A DECADE OF BRIDGES

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Frontispiece. CONSTRUCTION VIEW—LORAIN-CARNEGIE BRIDGE
CLEVELAND, OHIO

A DECADE OF BRIDGES

1926 — 1936

BY

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INTRODUCTION
BY
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J. H. JANSEN — CLEVELAND, O.

1937

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INTRODUCTION

PAUL P. CRÉT, F.A.I.A., A.N.A.

A great engineer, in a foreword to his admirable textbook on Masonry Bridges, wrote,—"Large masonry arches are constructed out of the knowledge gained from existing arches. It is a matter of experience. . . . This book attempts to show what was done, what must be done, what must not be done."

Without this solid basis of examples tested by time, with their merits and faults stimulating our critical faculties and challenging our ability to go a step farther, modern problems would find us helpless. Engineering, like any other science or art, is the sum of past efforts much more than an individual creation. This is why the preceding volume of Dr. Wilbur Watson, with its selected photographs of the most notable bridges, answered an urgent need. The present volume will be found its indispensable supplement.

The science of bridge building is the best illustration of the slow growth of a technique, where each generation brings its stone to the monument, each worker, whatever his personal talent, being indebted to his predecessors for the best part of his knowledge. "Bridge Architecture" showed this chain stretching from the Roman Empire to 1926; "A Decade of Bridges" brings it up to date. The title of the first volume, "Bridge Architecture," was aptly chosen. Leaving to technical publications the description of the construction features, the author kept chiefly in view the forms resulting from the structural scheme selected by the engineer. Architectural treatment was his first concern, and here he is in accord with the new standpoint of the country's best engineers, who recognize that designing a structure to carry a highway safely across a river or valley is only part of the problem. To quote Dr. Watson,—"It is highly desirable that utilitarian structures, such as bridges, should be as pleasing to the eye as it is practicable to make them, and that there should be greater collaboration between the Architect and the Engineer, with a realization on the part of each that science without art is apt to be unattractive, and art without science inefficient." Where this collaboration has been harmonious, you will find the most satisfactory bridges. Before the divorce of architecture and engineering, which took place in the middle of the XVIIIth Century, the French students of the Ecole des Ponts et Chaussées either received a first training in an architect's office before specializing for the government service, or were requested, while in the School, to attend a course in Architecture, given at that time by the famous architect, Francois Blondel. The present method of collaboration between the two professions can be equally successful. In this collaboration, the engineer's part is undoubtedly the more important. The architect may play second fiddle,

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but musicians know that the disparaging implication of these words is entirely unjustified, and that each part is vital to the score. The architect must constantly bear in mind that strength and dignity of design is achieved not by dissembling but by emphasizing structural purpose. Here, we will often find the engineer confronted by more than one solution to constructive problems, without valuable reasons to decide his ultimate choice. The architect's special training in form appreciation qualifies him to choose the construction scheme most likely to give distinction and significance to the work. This is not a question of "trimming", of adding ornament, but a sensitive perception of the character and spirit proper to a certain use of materials.

The prominent place occupied by bridges in our cities and countryside requires the best efforts of the engineer, the architect and the city planner. This is increasingly recognized, and the comments and illustrations of "A Decade of Bridges" bear witness to the continuous progress in this direction here and abroad.

TABLE OF CONTENTS

Page

INTRODUCTION BY PAUL P. CRET v

PREFACE ix

LIST OF STRUCTURES xi

LIST OF ILLUSTRATIONS xiii

THE BRIDGE BUILDERS—APPENDIX A 113

BIBLIOGRAPHY—APPENDIX B 119

PREFACE

This book was originally intended to be in the nature of a supplement to "Bridge Architecture," published in 1927, but because of the great number of notable bridges that have been completed during the last ten years, and the unprecedented size of many of them, it seemed advisable to publish this data as an entirely separate and independent book.

"Bridge Architecture" is a compilation of photographs of the world's most famous bridges, from the earliest times to the year 1926, especially selected to illustrate the architectural and historical development of bridges. The present book, while not overlooking the architectural features of recent structures, contains engineering and descriptive data which will be of value both to engineers and architects. But, as in the earlier work, the intention of the author is to present, primarily, a photographic record of the progress of the art.

Material help has been received in compiling this data from Mr. F. H. Frankland, Director of Engineering of the American Institute of Steel Construction; Mr. Paul P. Crét, Architect; the American Bridge Company; the Portland Cement Association; the Indiana Limestone Company; State Highway Officials, and from many engineers and architects to whom credit has been given in the text. Much of the descriptive and engineering data has been abstracted from various technical journals, especially from "The Engineering News-Record" and "Civil Engineering."

Appendix A lists the principal contracting firms responsible for the construction of these bridges. Credit has been given in general to the chief engineers and the collaborating architects in the text or on the cuts, but it should be recognized that the design and construction of modern bridges of notable size require the services of many engineers, architects, and contractors, whose names have been omitted to conserve space. Most of the photographs have been furnished by the engineers or the architects responsible for the design. When more than one illustration of a bridge is included, the names of the engineers and architects are given but once, usually in the title of the first illustration.

While one hundred bridges have been included in the text, this does not include all the important structures that have been built in the last decade: many notable bridges are not included, the author having selected only those which, in his opinion, contained novel engineering or architectural features, or served to illustrate modern tendencies in bridge design. Of these, about seventy have been selected for illustrating.

No effort has been made to give complete descriptions of these bridges; in many cases only a simple reference to the structure is included in the text, but in Appendix B will be found references to more complete descriptions in the technical press.

To Miss Sara R. Watson, Ph.D., I am indebted for assistance in editing the text.

Wilbur J. Watson.

January, 1937.

LIST OF BRIDGES

Page
Albany, New York, Bridge over the Hudson River 1
Bayonne, New Jersey, Bridge over the Kill van Kull 1
Bear Mountain, New York, Bridge over the Hudson River 4
Buffalo, New York, The Peace Bridge over the Niagara River 4
California State Highway Department Bridges, Bixby Creek Bridge, etc. 5
Canon City, Colorado, Bridge over the Royal Gorge 7
Cape Cod, Massachusetts, Bridges over the Cape Cod Canal 9
Carquinez Straits, California, Highway Bridge 7
Castelmoron, France, Bridge over the River Lot 8
Catskill, New York, Rip Van Winkle Bridge over the Hudson River 8
Cincinnati, Ohio, Railway Bridge over the Ohio River 10
Cleveland, Ohio, Lorain-Carnegie Bridge over the Cuyahoga River Valley 11
Cleveland, Ohio, Lorain Road Viaduct over Rocky River 16
Cleveland, Ohio, Hilliard Road Bridge over Rocky River 11
Cologne, Germany, The Cologne-Mülheim Bridge over the Rhine 16
Columbia, Pennsylvania, Bridge over the Susquehanna River 19
Crown Point, New York, Bridge over Lake Champlain 19
Denmark, Bridge over the Little Belt 23
Detroit, Michigan, Ambassador Bridge over the Detroit River 20
Eyne, Belgium, Memorial Bridge 23
Florianapolis, Brazil, Suspension Bridge 26
Freeport, Illinois, Krape Park Bridge 27
Grand Canyon, Arizona, Kaibab Trail Suspension Bridge 27
Grand Canyon, Arizona, Arch Bridge over the Colorado River 27
Grand Island, New York, Niagara River Bridges 28
Grand-Mere, Quebec, Suspension Bridge 27
Harrisburg, Pennsylvania, Market Street Bridge over the Susquehanna River 30
Harrisburg, Pennsylvania, Soldiers and Sailors Memorial Bridge 30
Koblenz, Germany, Adolph Hitler Bridge over the Moselle River 30
La Roche-Guyon, France, Bridge over the Seine River 33
London, England, New Thames River Bridges 33
Longview, Washington, Bridge over the Columbia River 34
Louisville, Kentucky, The Municipal Bridge 34
Louisville, Kentucky, The K. & I. Terminal R. R. Bridge 35
Maysville, Kentucky, Highway Bridge over the Ohio River 37
Minneapolis, Minnesota, Ford Bridge over the Mississippi River 37
Minneapolis, Minnesota, Fort Snelling-Mendota Bridge over the Mississippi River 37
Montreal, Canada, Harbor Bridge over the St. Lawrence River 38
Morgan City, Louisiana, Atchafalaya Bridge 38
Newcastle, England, The New Tyne Bridge 40
New Orleans, Louisiana, The Huey P. Long Bridge over the Mississippi River 40
Newport News, Virginia, Bridge over the James River 42
New Jersey, Pulaski Highway Bridge over the Passaic River 44
New York, New York, The George Washington Bridge over the Hudson River 44
New York, New York, Reconstruction of the Aqueduct Bridge 52

LIST OF BRIDGES, Continued

Page

New York, New York, The Triborough Bridge . . . 53
New York, New York, The Hendrik Hudson Bridge . . . 43
Ohio State Highway Bridges . . . 56
Oregon, State Highway Bridges . . . 56
Paducah, Kentucky, Highway Bridge over the Ohio River . . . 60
Paris, France, Pont de la Tournelle . . . 60
Philadelphia, Pennsylvania-Camden Bridge over the Delaware River . . . 60
Philadelphia, Pennsylvania, Pennsylvania Railroad Bridges . . . 64
Philadelphia, Pennsylvania, Tacony-Palmyra Bridge over the Delaware River . . . 60
Pittsburgh, Pennsylvania, Recent Bridges . . . 64
    Thirty-First Street Bridge over the Allegheny River
    Fortieth Street Bridge over the Allegheny River
    Sixteenth Street Bridge over the Allegheny River
    Sixth, Seventh and Ninth Street Bridges over the Allegheny River
    New Point Bridge
    West End-North Side Bridge over the Ohio River
    McKees Rocks Bridge over the Ohio River
    George Westinghouse Bridge
Plougastel, France, Bridge over the Elorn River . . . 72
Point Pleasant, West Virginia, Bridge over the Ohio River . . . 73
Poughkeepsie, New York, The Mid-Hudson Bridge . . . 75
Providence, Rhode Island, Washington Street Bridge . . . 76
Quebec, Canada, Bridge at Ile d'Orleans . . . 76
Rhode Island, The Mt. Hope Bridge . . . 76
Rochester, New York, The Veterans Memorial Bridge over the Genesee River . . . 78
Rockford, Illinois, Small Bridges . . . 81
Rogue River Bridge, Oregon . . . 82
St. Joseph, Missouri, Highway Bridge over the Missouri River . . . 83
St. Paul, Minnesota, Robert Street Bridge . . . 83
San Francisco, California, The San Francisco-Oakland Bay Bridge . . . 84
San Francisco, California, The Golden Gate Bridge . . . 92
Seattle, Washington, Lake Union Bridge . . . 96
South Africa, Birchenough Bridge over the Sadi River . . . 96
Spain, Railroad Bridge over the Elsa River . . . 96
Staten Island, New York-New Jersey Bridges over the Arthur Kill . . . 96
Stockholm, Sweden, Tranberg Sound Bridge . . . 97
Suisun Bay, California, Southern Pacific Railway Bridge . . . 97
Sydney, New South Wales, Bridge over Sydney Harbor . . . 99
Syracuse, New York, Grade Crossing Bridges . . . 101
Toledo, Ohio, Highway Bridge over the Maumee River . . . 102
Vancouver, British Columbia, Burrard Street Bridge . . . 102
Vicksburg, Mississippi, Highway Bridge over the Mississippi River . . . 102
Vincennes, Indiana, Memorial Bridge . . . 103
Waldo-Hancock Bridge, Maine . . . 103
Washington, District of Columbia, Arlington Memorial Bridge . . . 104
Washington, District of Columbia, Calvert Street Bridge . . . 107
Westchester County, New York, Bridges . . . 107

LIST OF ILLUSTRATIONS

Frontispiece—The Lorain-Carnegie Bridge, Cleveland, Ohio, Construction View . . . . Page

1. Bayonne, New Jersey, Bridge over the Kill van Kull xvi
2. Bayonne, New Jersey, Bridge over the Kill van Kull, Architect's Drawing 2
3. Bayonne, New Jersey, Bridge over the Kill van Kull, as built 2
4. Buffalo, New York, The Peace Bridge over the Niagara River, Photo 4
5. Buffalo, New York, The Peace Bridge over the Niagara River, Diagram 5
6. California State Highway Bridges, Bixby Creek Bridge 6
7. California State Highway Bridges, Douglas Memorial Bridge, Detail 6
8. California State Highway Bridges, Sacramento River Bridge, Sacramento 7
9. California State Highway Bridges, The Harlan D. Miller Bridge 8
10. Cape Cod Canal, Massachusetts, Railroad Lift Bridge 9
11. Cape Cod Canal, Massachusetts, Highway Bridges 10
12. Cleveland, Ohio, The Lorain-Carnegie Viaduct, General View 12
13. Cleveland, Ohio, The Lorain-Carnegie Viaduct, Pylons 12
14. Cleveland, Ohio, The Lorain-Carnegie Viaduct, Columbus Road Crossing 13
15. Cleveland, Ohio, The Lorain-Carnegie Viaduct, Pylons 13
16. Cleveland, Ohio, The Lorain-Carnegie Viaduct, Diagram 14
17. Cleveland, Ohio, Lorain Road Bridge over Rocky River Valley, General View 17
18. Cleveland, Ohio, Lorain Road Bridge over Rocky River Valley, Detail 17
19. Cleveland, Ohio, Lorain Road Bridge over Rocky River Valley, Detail 17
20. Cologne, Germany, Cologne-Mülheim Bridge over the Rhine, Photo 18
21. Cologne, Germany, Cologne-Mülheim Bridge over the Rhine, Diagram 18
22. Crown Point, New York, Bridge over Lake Champlain, Photo 20
23. Crown Point, New York, Bridge over Lake Champlain, Diagram 20
24. Detroit, Michigan, Ambassador Bridge over Detroit River, General View 21
25. Detroit, Michigan, Ambassador Bridge over Detroit River, Medallion 21
26. Detroit, Michigan, Ambassador Bridge over Detroit River, Diagram 25
27. Eyne, Belgium, Memorial Bridge over Scheldt River, General View 23
28. Eyne, Belgium, Memorial Bridge over Scheldt River, Detail 26
29. Florianapolis, Brazil, Suspension Bridge, Diagram 27
30. Freeport, Illinois, Krape Park Bridge 28
31. Grand Island, New York, Bridges over Niagara River 29
32. Harrisburg, Pennsylvania, Market Street Bridge over Susquehanna River 31
33. Harrisburg, Pennsylvania, Soldiers & Sailors Memorial Bridge, Pylons 32
34. Harrisburg, Pennsylvania, Soldiers & Sailors Memorial Bridge, Sculpture 32
35. London, England, Lambeth Bridge, Diagram 33
36. Louisville, Kentucky, Municipal Bridge over the Ohio River, Pylons 35
37. Louisville, Kentucky, Municipal Bridge over the Ohio River, Sculpture 36
38. Louisville, Kentucky, Municipal Bridge over the Ohio River, Medallions 36
39. Louisville, Kentucky, Kentucky & Indiana Terminal R. R. Bridge over Broadway 37
40. Minneapolis, Minnesota, The Ford Bridge over the Mississippi River 38

LIST OF ILLUSTRATIONS, Continued Page

41. Morgan City, Louisiana, Bridge over the Atchafalaya River 39
42. Newcastle, England, The new Tyne Bridge 39
43. New Orleans, Louisiana, The Huey P. Long Bridge over the Mississippi River, Diagram 41
44. New Jersey, Pulaski Highway Bridge over the Passaic River 43
45. New York City, New York, The George Washington Bridge over the Hudson River, General View 45
46. New York City, New York, The George Washington Bridge over the Hudson River, Tower Detail 46
47 New York City, New York, The George Washington Bridge over the Hudson River, West Approach 47
48. New York City, New York, The George Washington Bridge over the Hudson River, Detail 49
49. New York City, New York, The George Washington Bridge over the Hudson River, General Diagram 50
50. New York City, New York, The George Washington Bridge over the Hudson River, Cross Section 50
51. New York City, New York, The George Washington Bridge over the Hudson River, Diagram—Tower Elevations 52
52. New York City, New York, Reconstruction of "High Bridge", Photo 53
53. New York City, New York, Reconstruction of "High Bridge", Diagram 53
54. New York City, New York, The Triborough Bridge, General View 54
55. New York City, New York, The Triborough Bridge, Little Hell Gate span 54
56. New York City, New York, The Triborough Bridge, Harlem River Span 55
57. New York City, New York, The Triborough Bridge, Bronx Kills span 56
58. Ohio—State Highway Bridges, Port Clinton Bridge 57
59. Ohio—State Highway Bridges, Brookpark Bridge 57
60. Ohio—State Highway Bridges, Brookpark Bridge railing 58
61. Oregon—State Highway Bridges, Diagrams 59
62. Paris, France, The new Pont de la Tournelle, general view 61
63. Paris, France, The new Pont de la Tournelle, detail of shaft 61
64. Philadelphia, Pennsylvania, Philadelphia-Camden Bridge over Delaware River 62
65. Philadelphia, Pennsylvania, Philadelphia-Camden Bridge over Delaware River 63
66. Philadelphia, Pennsylvania, Pennsylvania Railroad Bridge over 31st Street 65
67. Pittsburgh, Pennsylvania, Sixth Street Bridge over the Allegheny River 65
68. Pittsburgh, Pennsylvania, Fortieth Street Bridge over the Allegheny River 66
69. Pittsburgh, Pennsylvania, Thirty-first Street Bridge over the Allegheny River 66
70. Pittsburgh, Pennsylvania, Ohio River Bridges, Diagrams 67
71. Pittsburgh, Pennsylvania, The George Westinghouse Bridge 70
72. Pittsburgh, Pennsylvania, The George Westinghouse Bridge, Diagram 70
73. Ploughgastel, France, Bridge over the Elorn River, Centering 73
74. Ploughgastel, France, Bridge over the Elorn River, Diagram 74

LIST OF ILLUSTRATIONS, Continued Page

75. Point Pleasant, West Virginia, Suspension Bridge over the Ohio River, Diagram 75
76. Poughkeepsie, New York, Mid-Hudson Bridge 75
77. Rhode Island, The Mt. Hope Bridge by night 77
78. Rochester, New York, The Veteran's Memorial Bridge over the Genesee River, Photo 79
79 Rochester, New York, The Veteran's Memorial Bridge over the Genesee River, Diagram 80
80. Rockford, Illinois, Small Bridges (3 illustrations) 81
81. St. Paul, Minnesota, Robert Street Bridge over the Mississippi River 82
82. San Francisco, California, San Francisco-Oakland Bay Bridge, General View 83
83. San Francisco, California, San Francisco-Oakland Bay Bridge, West Crossing 85
84. San Francisco, California, San Francisco-Oakland Bay Bridge, Anchor Pier 86
85. San Francisco, California, San Francisco-Oakland Bay Bridge, Suspension Tower 87
86. San Francisco, California, San Francisco-Oakland Bay Bridge, Tunnel Entrance 88
87 San Francisco, California, San Francisco-Oakland Bay Bridge, Diagram 88-91
88. San Francisco, California, The Golden Gate Bridge, Air View 93
89. San Francisco, California, The Golden Gate Bridge, Tower 94
90. San Francisco, California, The Golden Gate Bridge, Diagram 95
91. Suisun Bay, California, Southern Pacific Railway Bridge, Photo 98
92. Suisun Bay, California, Southern Pacific Railway Bridge, Diagram 98
93. Sydney, New South Wales, Australia, Bridge over Sydney Harbor 100
94. Sydney, New South Wales, Australia, Bridge over Sydney Harbor, Details 101
95. Waldo-Hancock Bridge over the Penobscot River, Maine, Photo 103
96. Waldo-Hancock Bridge over the Penobscot River, Maine, Diagram 104
97. Washington, District of Columbia, The Arlington Bridge, General View 105
98. Washington, District of Columbia, The Arlington Bridge, Pylons 105
99. Washington, District of Columbia, The Arlington Bridge, Bascule span 106
100. Washington, District of Columbia, The Arlington Bridge, Sculpture 106
101. Washington, District of Columbia, Calvert Street Bridge, General view 108
102. Washington, District of Columbia, Calvert Street Bridge, Sculpture 108
103. Westchester County, New York, Bridge at Croton Lake 109
104. Westchester County, New York, Bridge 109
105. Port Arthur, Texas 110
106. Oregon, Coos Bay Bridge, Portal 111

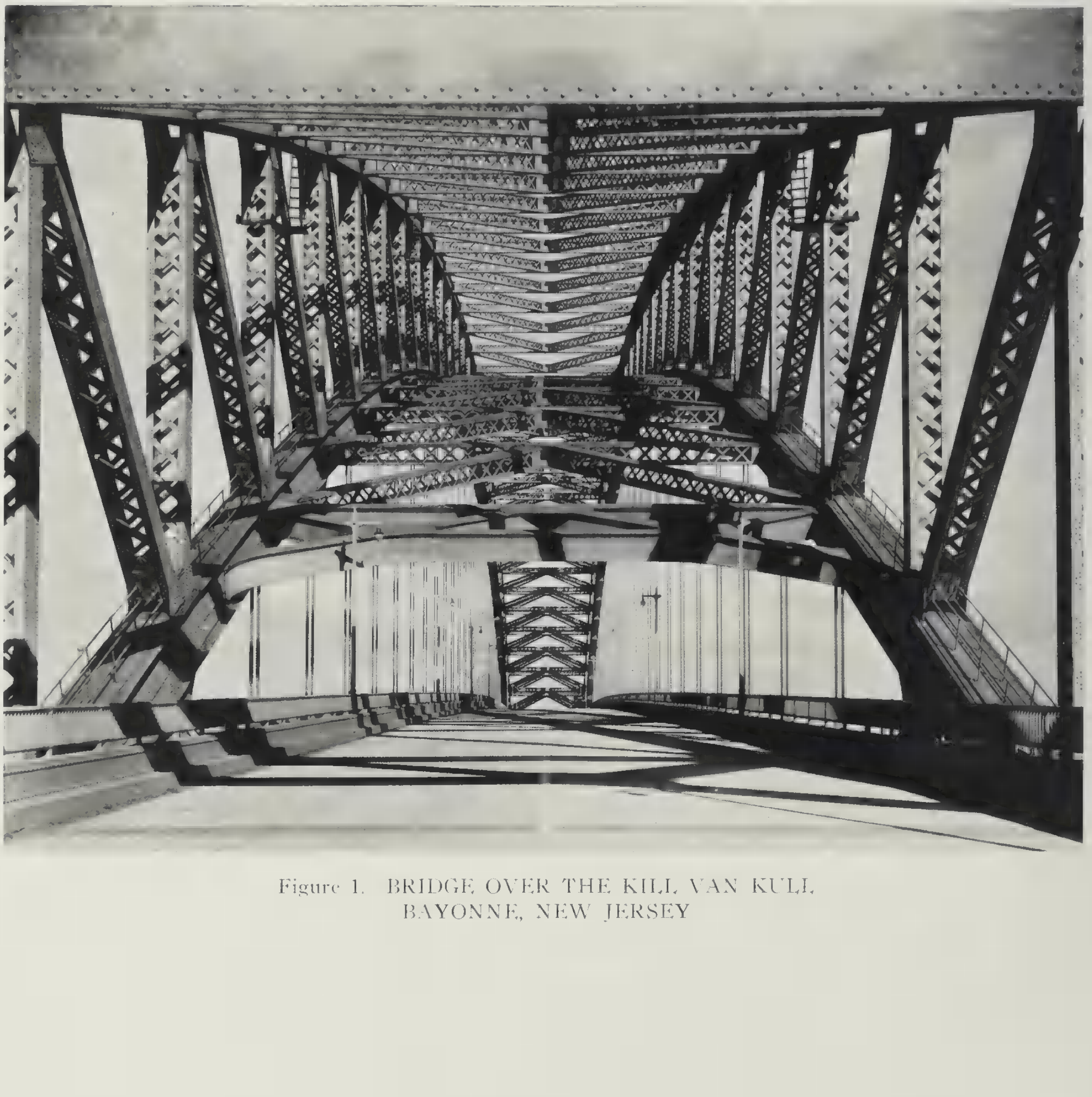


Figure 1. BRIDGE OVER THE KILL VAN KULL
BAYONNE, NEW JERSEY

A DECADE OF BRIDGES

ALBANY, NEW YORK, HUDSON RIVER BRIDGE

Built in 1933 by the Department of Public Works of the State of New York. This is a very heavy bridge of this type, weighing some 2,730 tons. It carries a 42 foot roadway and two 6 foot walks, and the lift span has a length between centers of piers of 348 feet. Waddell and Hardesty were consulting engineers for the lift span.

In the design of this bridge, which connects the City of Albany with Rensselaer across the river, silicon steel was largely used to keep down the weight of the lift span. In addition to the notable lift span, the structure comprises three fixed spans of through trusses, two of 222 feet, and one 167 feet in length. The lift span towers carry power cables at a height sufficient to clear the trusses when the span is raised. The operator's house is located at the center of the movable span. The roadway is composed of concrete slabs only 6½ inches thick in the case of the movable span, with a bituminous wearing surface.

Frederick S. Greene was superintendent of the Department of Public Works, and T. F. Farrell was chief engineer.

BAYONNE, NEW JERSEY, BRIDGE OVER THE KILL VAN KULL

This is one of the bridges built under the Port of New York Authority and spans the Kill van Kull between Bayonne, New Jersey, and Staten Island, New York. It is chiefly interesting because of its main feature, a steel arch of unprecedented length of span,—1,675 feet from center to center of arch bearings. The arch is of the through type, two hinged, with parabolic curved chords, the rise of the lower chord being 266 feet. The roadway passes through the arch ring and is suspended from it in the central part of the span on wire rope hangers and carried on columns at the ends. The arch chords are parabolic arcs, 37 feet 6 inches apart at the crown and 67 feet 6 inches apart at the abutments. The panels are 41 feet 3⅝ inches in length. Carbon-manganese steel was used for the lower chords of the arches and silicon steel for the upper chords, the former having an ultimate minimum strength of 90,000 lbs. per sq. in. and the latter 80,000. Carbon structural steel was used for secondary and some primary members. This is the first time that carbon-manganese steel was used in bridge construction. An idea of the magnitude of this arch may be obtained from its thrust against the skewbacks, amounting to almost 15,000 tons on each skewback, which is transmitted to the masonry by shoes having a base of 15 feet by 18 feet in size, and weighing 120 tons each. The clearance over the water is 150 feet. The deck carries a 40-foot roadway, which can be widened in the future to 65 feet and a 6 foot walk, which can be duplicated when needed. The roadway is a concrete slab 8½ inches thick, reinforced by bulb beams, spaced 15 inches on centers and riveted to transverse I beams, 5 feet 3 inches on centers,

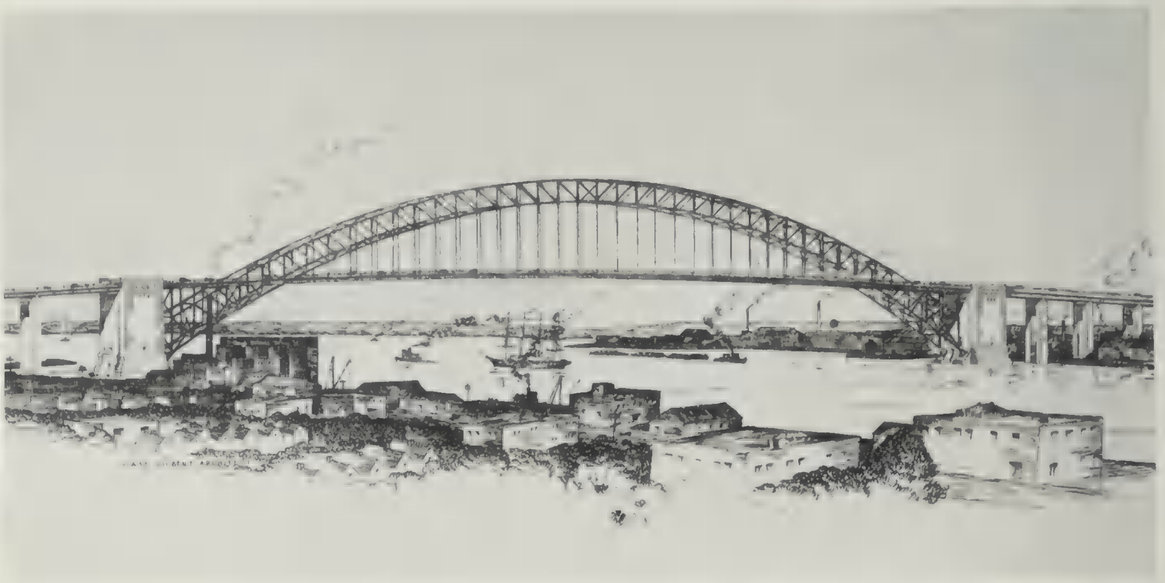


Figure 2. STEEL ARCH OVER THE KILL VAN KULL, AS DESIGNED
BAYONNE, NEW JERSEY
O. H. Amman, Chief Engineer *Cass Gilbert, Architect*

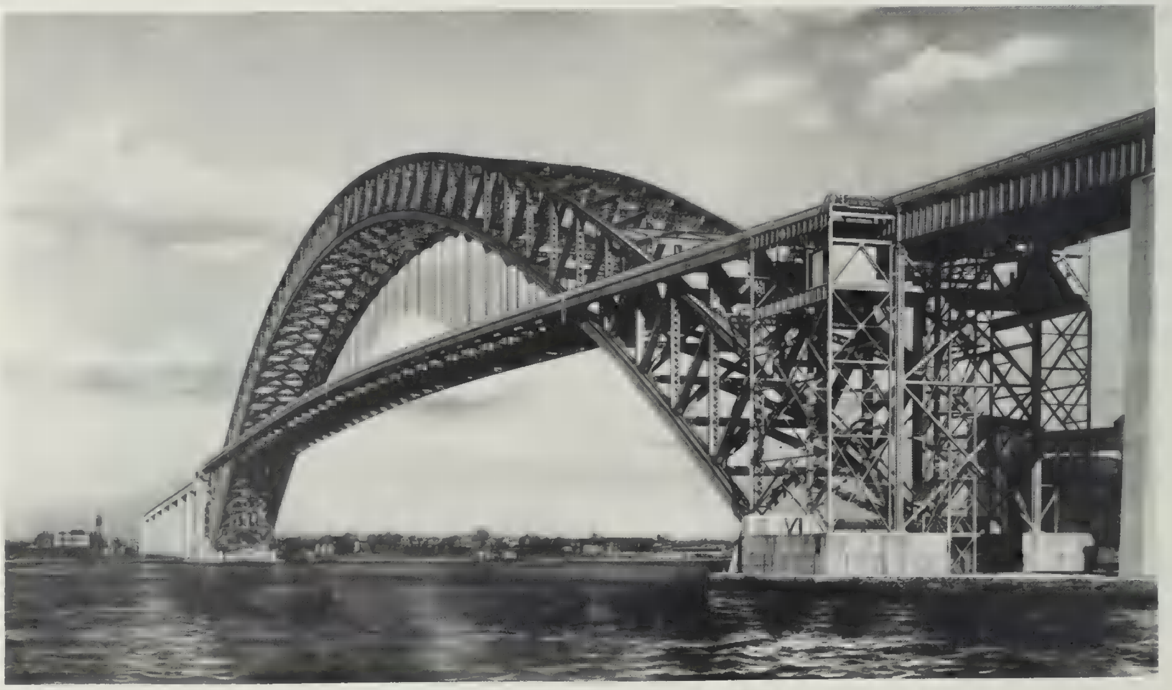


Figure 3. STEEL ARCH OVER THE KILL VAN KULL, AS BUILT
BAYONNE, NEW JERSEY

which in turn are carried on built-up longitudinal stringers. The presence of bed rock near the surface was of course favorable to the arch type of bridge for this location. Each abutment is about 133 feet by 107 feet in extreme dimensions; of concrete with granite facing and constructed by the open cofferdam method. Erection was carried out by use of temporary towers placed in the channel, which enabled the arch to be assembled as a series of cantilevers of comparatively short spans. As this arch is of the two-hinged type, hinged only at the skewbacks, it was necessary to place the closing chord member under its computed stress. Usually this is done by jacking the center member into place, first computing the stress that the member should carry under the weight of that part of the arch actually erected, and then applying this stress to the member by jacks before riveting into place. In closing the arch ribs of the Kill van Kull bridge, however, the placing of the last chord member, which, by the way, was not at the center, was accomplished by jacking up the entire arch to such a position that the stress in the closing member would be zero under the existing conditions, which enabled the closure to be made without applying any stress directly to the members—a very neat erection operation. Before work was started on this bridge, a scale model was made of engraver's brass, about 9 feet in length, and tested in the laboratory, the measured strains in the model serving as a check upon computed stresses and deflections. The plans for this bridge provided for massive concrete pylons, granite faced, at the abutments, which were to be purely decorative, but these have not yet been built. When these are completed, they will doubtless add greatly to the appearance of the structure.

This bridge was designed under the direction of Mr. O. H. Ammann, Chief Engineer of the Port Authority,—assisted by Leon S. Moisseiff, Advisory Engineer of Design; Edw. W. Stearns, Asst. Chief Engineer; Allston Dana, Engineer of Design; Wm. J. Boucher and Montgomery B. Case, Engineers of Construction; and R. T. Robinson, Resident Engineer.

Physical Data:

Length of arch span	1,675 feet
Total length of bridge including approaches	8,100 feet
Width of arch	74 feet
Channel clearance at midspan	150 feet
Rise, lower chord	274 feet
Height of upper chord, above water, at crown	327 feet
Steel work in arch and approaches	30,000 tons
Arch abutments, concrete and granite	34,000 cu. yds.
Approach piers, reinforced concrete	29,000 cu. yds.

The cost to date of this structure as it now stands amounts to about thirteen million dollars.

BEAR MOUNTAIN, NEW YORK, BRIDGE OVER HUDSON RIVER

A privately owned toll bridge located in a beautiful setting, and consisting of a wire cable suspended span of 1,632 feet center to center of towers. The roadway is 38 feet wide and two walks are 5 foot each wide. Designed by H. C. Baird.

This bridge, like many other toll bridges, has not been a financial success, and that it does not appeal to all as a thing of beauty is evidenced by the criticism of Laurence F. Abbott in the "Outlook" that "Bear Mountain Bridge designs look like a piece of tin trumpery." Possibly Mr. Abbott was somewhat prejudiced in favor of the more massive type of construction, an admirer of heavy lines.

BUFFALO, NEW YORK, THE PEACE BRIDGE

Named the Peace Bridge in commemoration of over a century of peace between the nations which it joins and so dedicated in the presence of many notables, including the then Prince of Wales, later King Edward VIII, at its opening in 1927, this structure consists of a series of deck steel arches over the Niagara River and a single through truss span of ordinary type at the Buffalo end over the Black Rock Canal. This bridge was financed and built by the Buffalo & Fort Erie Public Bridge Company, a private corporation, operating under grants that provide for its ultimate public ownership.

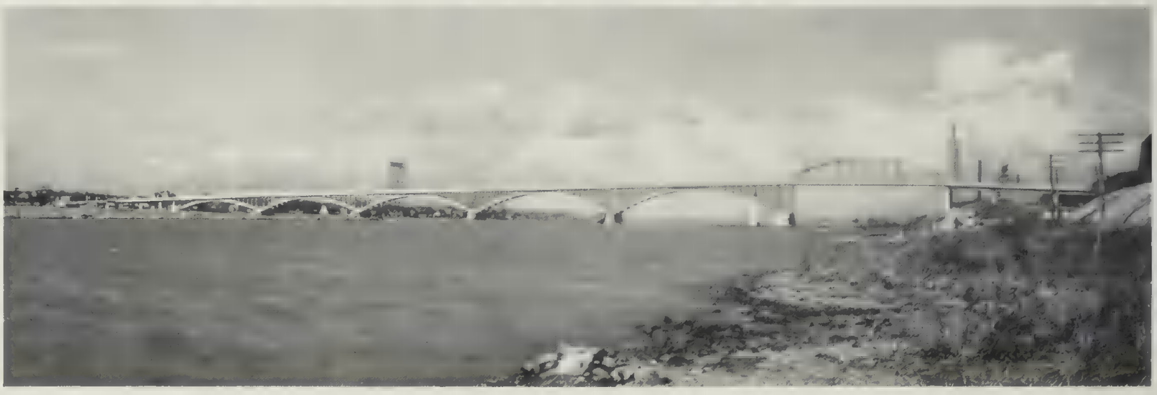
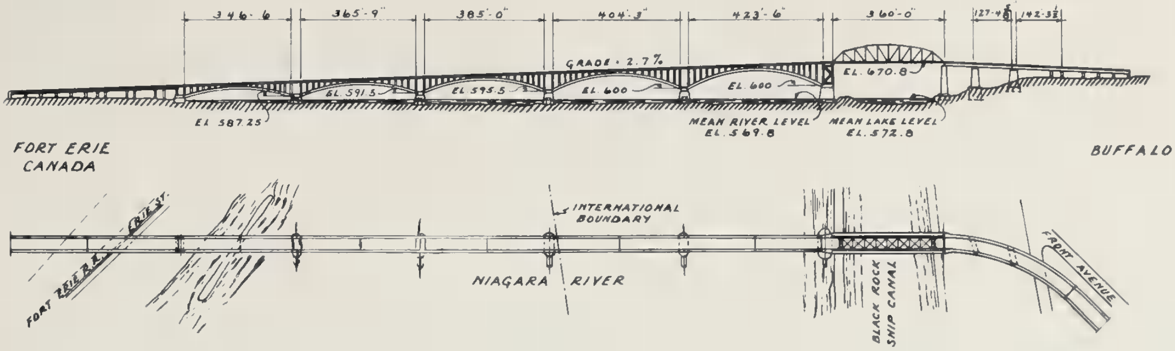


Figure 4. PEACE BRIDGE OVER THE NIAGARA RIVER, BUFFALO, NEW YORK
E. P. Lupfer, Chief Engineer *Wm. R. Davis, Designing Engineer*

It comprises five plate girder arches 423½ to 346½ feet in length over the river and a 360-foot through riveted span over the Black Rock Ship Canal, providing 100 feet clearance for boats. The roadway width is 36 feet and the two sidewalks are 7 feet wide. The pavement is 4-inch granite block on a 7-inch reinforced concrete slab.

The most interesting problem in connection with the design of this bridge was that of placing the cribs for the piers in from 14 feet to 19 feet of water with



· PLAN · AND · ELEVATION · OF · THE · PEACE · BRIDGE ·
BUFFALO N.Y.

Figure 5.

a normal current velocity of 8 to 10 feet per second, often increased to 14 feet by high winds, and carrying large quantities of ice in the spring from Lake Erie. This was done by means of large scows which were held by heavy anchors placed a considerable distance upstream and equipped with winches, by means of which the timber caissons, framed to fit the size of the piers, were pulled upstream to the correct position and sealed with underwater concrete. The bottom of the river is smooth rock, making this operation unusually difficult. From an aesthetic viewpoint, it is to be regretted that the steel arch motive could not be carried out the entire length of the bridge, the appearance of which is marred by the through truss span over the canal and the plate girder approach spans.

The system of erection of steel was somewhat unusual, the falsework consisting of steel bents resting on steel piling, driven to the bed rock, and protected by steel cribs or open baskets that offered but slight resistance to the current.

The traffic the first year was 1,407,272 vehicles which was four times the ferry traffic which the bridge displaced.

CALIFORNIA STATE HIGHWAY DEPARTMENT BRIDGES

The State of California, through its Highway Department, has constructed many notable bridges as a part of the development of its wonderful highway system, and of these bridges the majority are of reinforced concrete, characterized by long span arches supporting slender columns. Many of these are on curves and on grades, and located in isolated mountain districts. The Bixby Creek Bridge, illustration number 6, is a good example of this type of bridge, located at a picturesque spot on the Coast Highway. The arch has a span of 330 feet and a height of 270 feet above the water. Another handsome arch of 234 feet span across Dog Creek in Shasta County is named after the late Harlan D. Miller for many years bridge engineer for the Highway Department; and still another, over the Klamath River, in Del Norte County, in honor of G. H. Douglas, the entrances of which are characterized by huge grizzly bears on the end posts.

A lift bridge over the Sacramento River, completed in 1935 at a cost of nearly a million dollars, has a quite unusual treatment of the towers, and received honorable mention by the Jury of Awards of the American Institute of Steel Construction. The lift span is 209 feet 6 inches in length. The total length of the bridge is 738 feet.

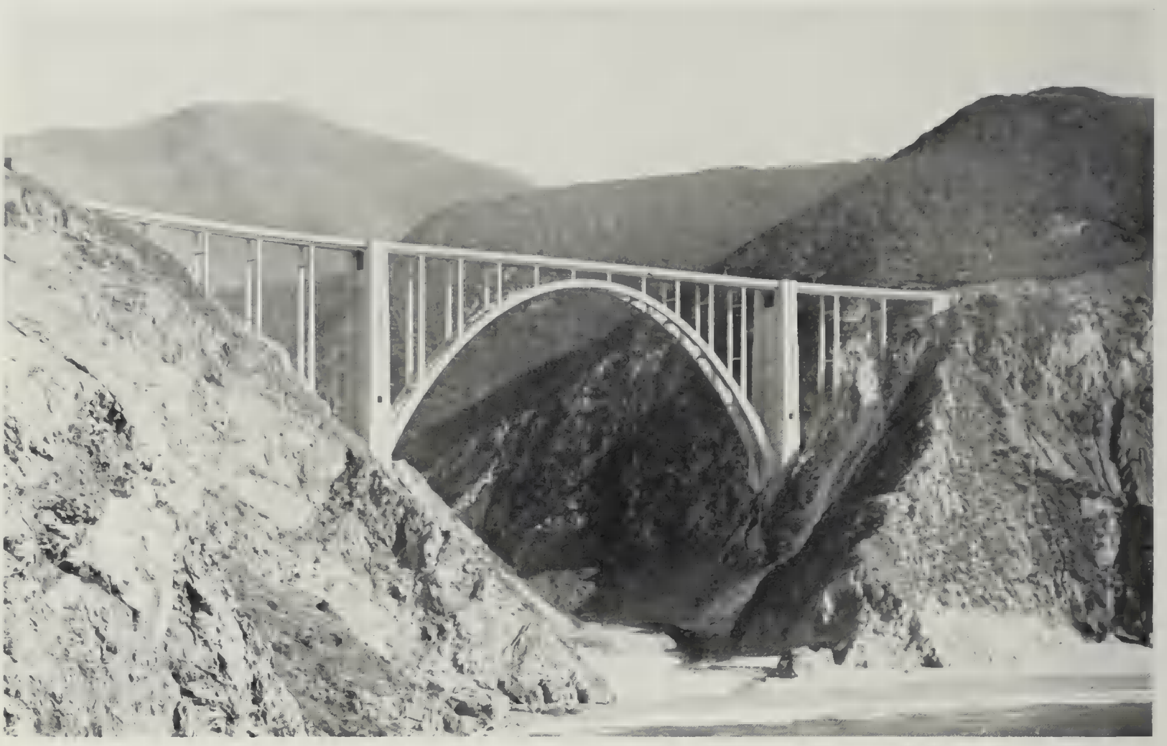


Figure 6. BIXBY CREEK BRIDGE, CALIFORNIA STATE HIGHWAYS
F. W. Penhorst, Acting Bridge Engineer—1933

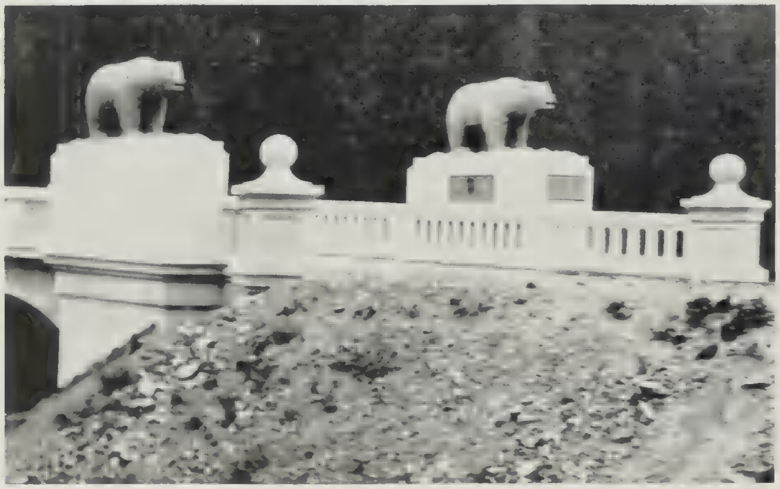


Figure 7. APPROACH TO DOUGLAS MEMORIAL BRIDGE, CALIFORNIA STATE HIGHWAYS
Harlan D. Miller, Bridge Engineer
State Highway Department
1926

Many other very creditable structures have been built by the California Highway Department, but the most spectacular and by far the largest is the San Francisco-Oakland Bay Bridge, which, while financed by a separate State Authority, has been built under the direction of the officials of the State Highway Department, headed by Mr. C. H. Purcell as Chief Engineer and Charles E. Andrews as Bridge Engineer.

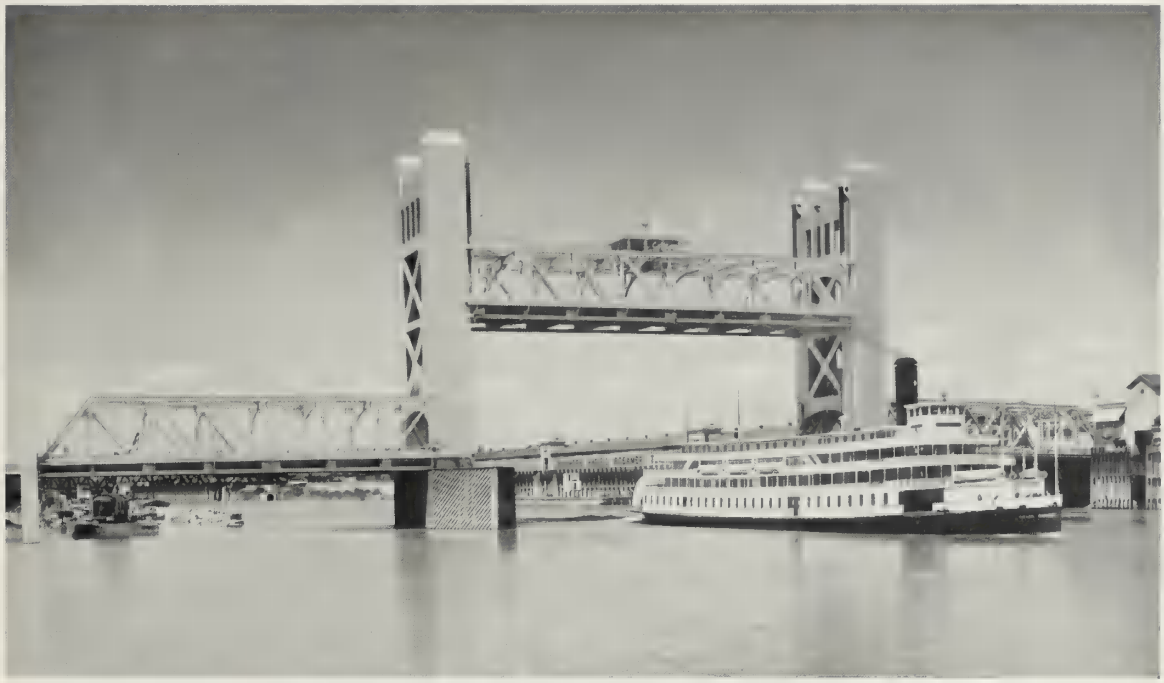


Figure 8. BRIDGE OVER SACRAMENTO RIVER, SACRAMENTO, CALIFORNIA
C. H. Purcell, State Highway Engineer — F. W. Panhorst, Acting Bridge Engineer

CANON CITY, COLORADO, BRIDGE OVER THE ROYAL GORGE

A suspension bridge of 880 feet main span and 190 and 130 feet side spans, chiefly notable for its setting over the Royal Gorge of the Arkansas River at a height of 1,053 feet above the famous "Hanging Bridge" of the Denver and Rio Grande R. R. built by C. Shaler Smith in 1878. The cables are of the parallel wire type. Engineer—Geo. E. Cole, Houston, Texas.

CARQUINEZ STRAITS, CALIFORNIA, HIGHWAY TOLL BRIDGE

A privately owned highway toll bridge, completed in May, 1927, and comprising twin cantilever spans each 1,100 feet in length, the piers for which are founded at a depth of 132 feet sunk by open dredging. The roadway is 30 feet wide with two 4-foot walks. Chas. Derleth, Jr., was Chief Engineer with W. H. Burr and D. B. Steinman as consultants.

CASTELMORON, FRANCE, HIGHWAY BRIDGE OVER RIVER LOT

The distinguishing features of this reinforced concrete through or overhead arch bridge are the use of inclined hangers of steel rods, of precast sections for the cores of the arch ribs, and of the unusual arrangement of hinges.

The bridge has a span of 470 feet, one of the longest of its type, and carries an 18 foot roadway and two 3 foot, 3 inch walks. Hinges are placed at the intersection of the roadway and the arch ribs, a distance apart of 393.6 feet, and a third hinge was placed at one end of the arch ribs. It is claimed that inclining the hangers reduces the bending moment in the arch ribs, as does also this placing of the hinges.

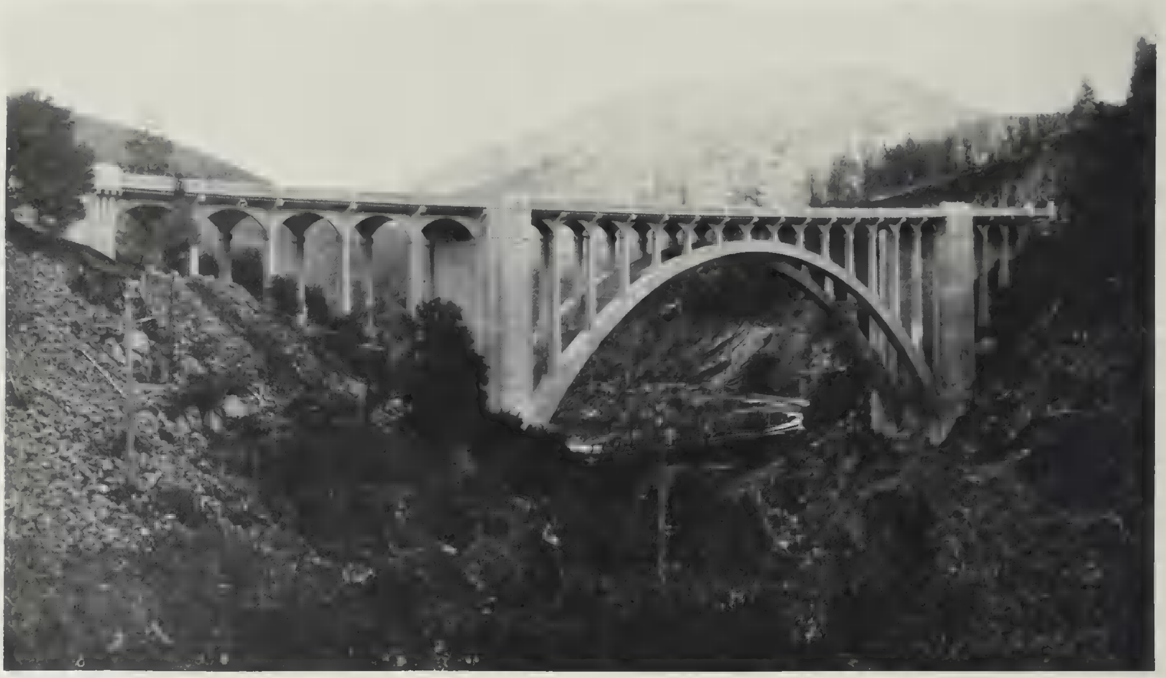


Figure 9. THE HARLAN D. MILLER MEMORIAL BRIDGE IN SHASTA COUNTY CALIFORNIA STATE HIGHWAYS—1927

The cross section of the ribs at the crown is 3 feet 11 inches high and 3 feet 3 inches wide. The precast cores of the arch rib constituted somewhat less than one-half of the completed section, the envelope surrounding them being poured after the core had been stressed to the proper amount by jacks placed at the crown. It is claimed that a much better distribution of stress in the ribs under live load is obtained in this way. This bridge was completed in 1933 by the firm of Christian and Nielson, Mr. A. E. Bretting, Chief Engineer.

CATSKILL, NEW YORK, THE RIP VAN WINKLE BRIDGE OVER THE HUDSON

A publicly owned toll bridge built by the State and comprising an 800 foot cantilever span with 400 foot anchor arms, which provide 142 foot clearance for navigation. The east approach consists of ten 330 foot deck truss spans. The east main pier was founded by sinking a pneumatic caisson through an artificial, submerged, sand island formed by dumping material to an elevation of about 10 feet below water level. The designing engineer was Glen B. Woodruff.

CAPE COD, MASSACHUSETTS, BRIDGES OVER THE CAPE COD CANAL

Three large bridges, two of which are fixed, continuous-truss type high-level structures for highways providing a vertical clearance of 135 feet, and one of which is a railroad lift span with a record length of 544 feet, have been built over the Cape Cod Canal in the improvement of that waterway. One of these highway bridges is known as the Bourne bridge located near the west or Buzzards Bay end of the Canal, and the other as the Sagamore Bridge, near the Cape Cod Bay end. In general appearance these two are quite similar to the Lake Champlain Bridge, previously built under the direction of the same engineers. They have center spans of 616 feet and side spans of 396 feet. The roadway width is 40 feet, flanked by one 6-foot walk, and the roadway wearing surface is a 2-inch bituminous finish on a 7-inch concrete slab. Stepped curbs 16 inches high are used. The floor platform is hung from the trusses by pre-

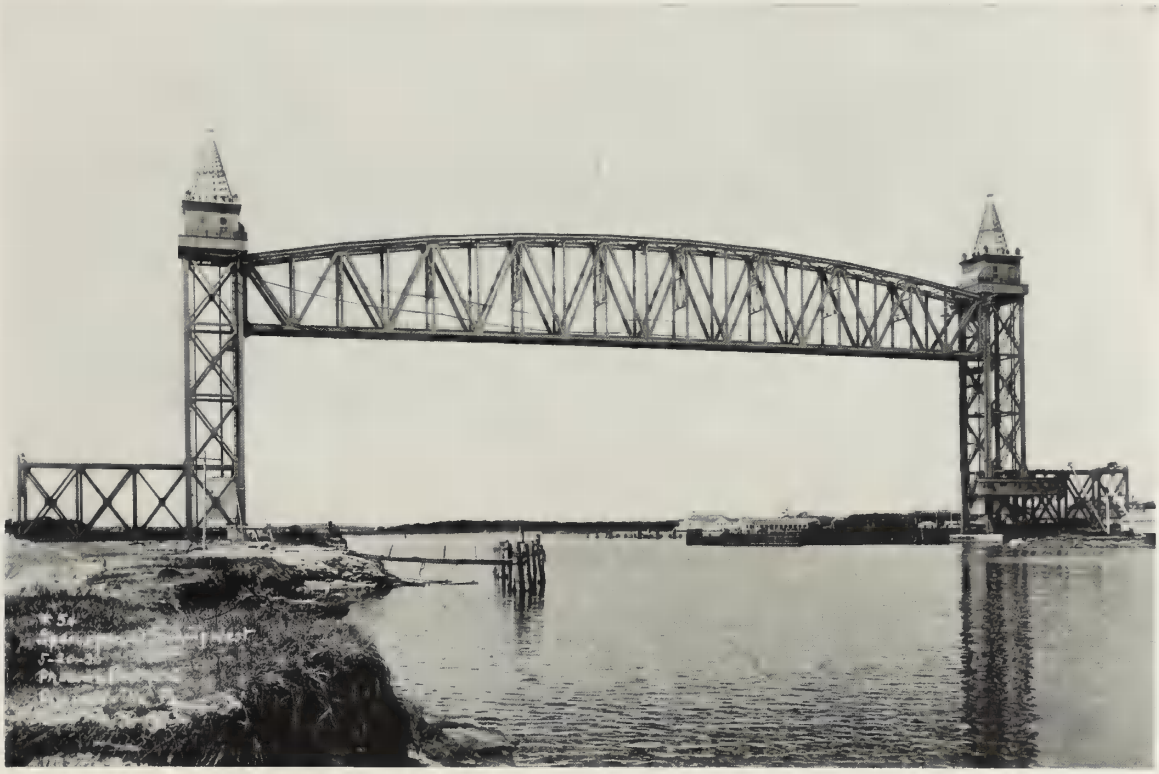


Figure 10. RAILROAD BRIDGE OVER CAPE COD CANAL, CAPE COD, MASSACHUSETTS
Parsons, Klapp, Brinckerhoff & Douglas, Engineers
McKim, Meade & White, Architects

stressed cables. The main piers were planned to rest on gravel at an elevation 52 to 54 feet below sea level and were constructed of concrete with granite facing at the water line.

In driving the steel sheet piling for the cofferdams used in the construction of these piers, a large number of boulders were encountered in the sand and gravel formation. These were so numerous and large that changes in plans were required, necessitating timber piling in some cases. In order to unwater the cofferdams, resort was had to the "well-point system," consisting in driving rings of closely spaced well-points (perforated pipes connected above ground by a pipe "header," which in turn is connected to pumps). In this way the ground water around the caisson was pumped out or lowered, causing the hydrostatic pressure on the cofferdam walls to be greatly reduced. The long lift span for the railroad is considered to be the most handsome of its type ever built, careful study having been made by the architect to attain this result. The huge sheaves (15 feet diameter in this case) are housed in and the houses covered with a conical roof which constitutes a finial to the towers,—a practical demonstration that bridges of this type need not be offensively ugly.

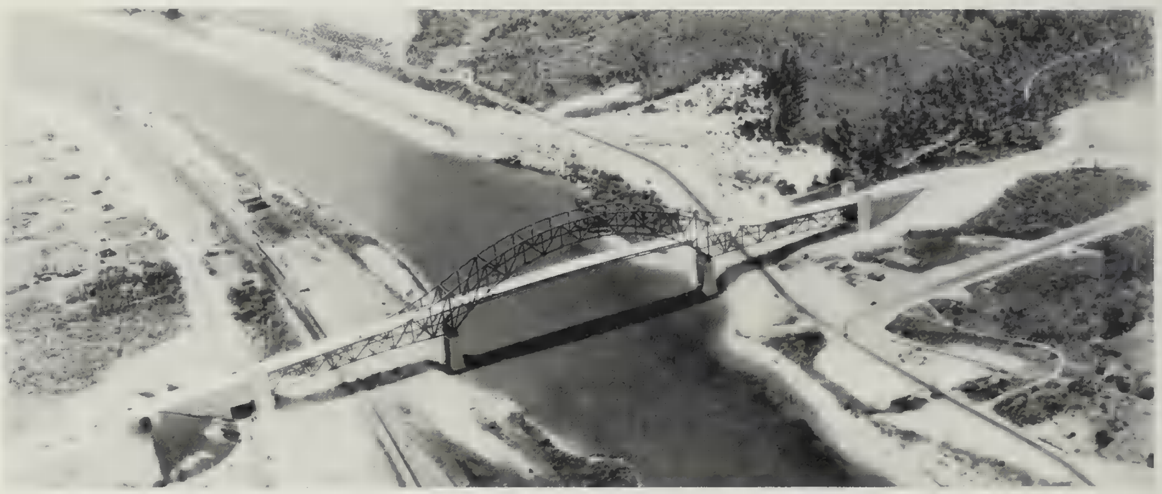


Figure 11. HIGHWAY BRIDGE OVER CAPE COD CANAL, BOURNE, MASSACHUSETTS
Fay, Spofford & Thorndike, Engineers *Cram & Ferguson, Architects*

The Bourne Bridge received the First Prize in Class A of the American Institute of Steel Construction award for 1935, and the Sagamore Bridge received Honorable Mention in the 1936 award.

CINCINNATI, OHIO, CHESAPEAKE & OHIO RY. BRIDGE OVER THE OHIO RIVER

The old bridge was rebuilt in 1928, with continuous trusses over four supports, the center span 675 feet long and side spans 450 feet each. The new structure is double tracked and designed for very heavy loading (E70). Engineers were J. E. Greiner Co., Baltimore.

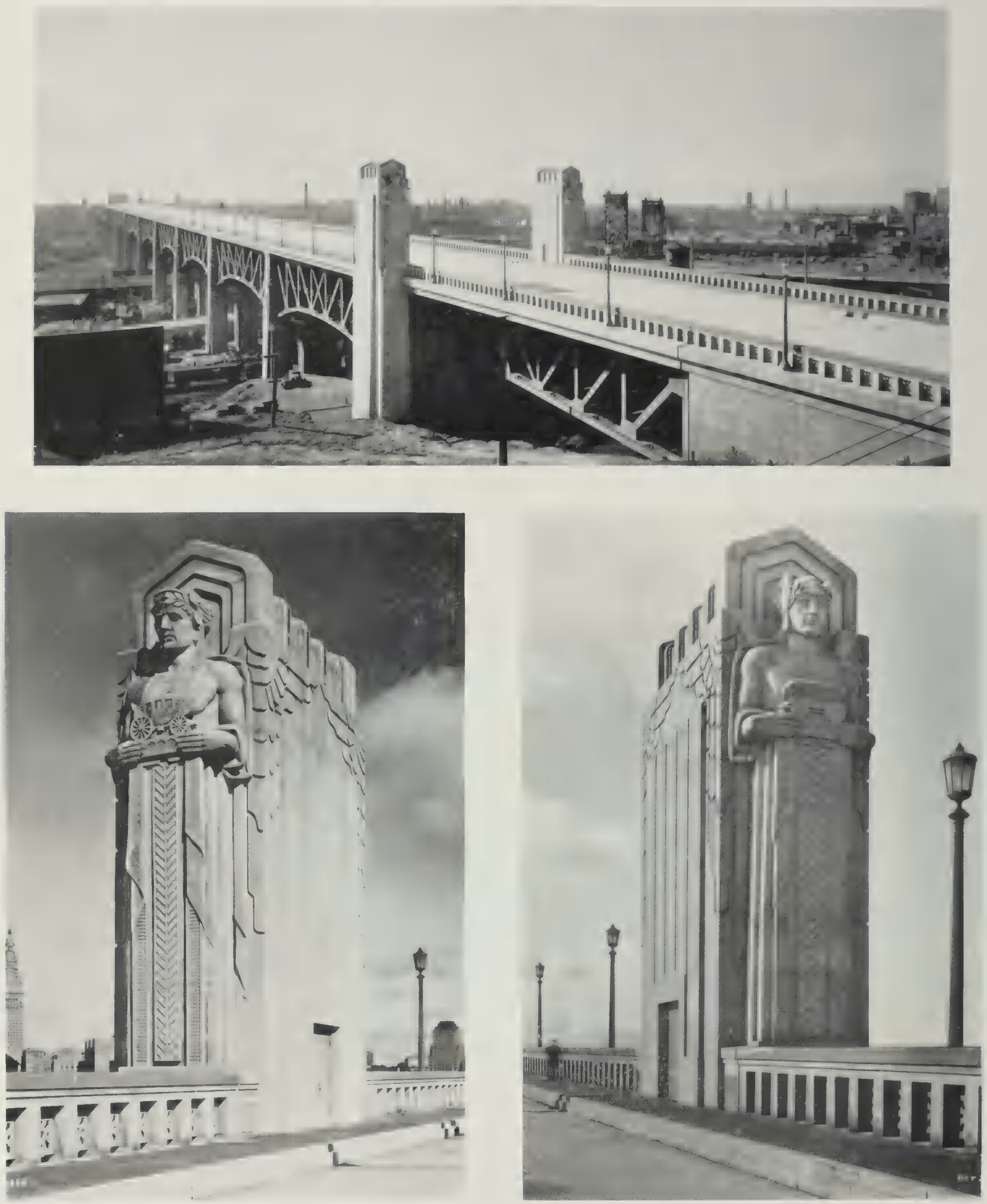
CLEVELAND, OHIO, HILLIARD ROAD BRIDGE OVER ROCKY RIVER VALLEY

A reinforced concrete viaduct spanning the Metropolitan Parkway and Rocky River. Built 1926. Engineer, A. M. Felgate, Bridge Engineer, Cuyahoga County, Ohio. The design is of the open spandrel ribbed type, the most notable feature being the use of pronounced batters on the piers.

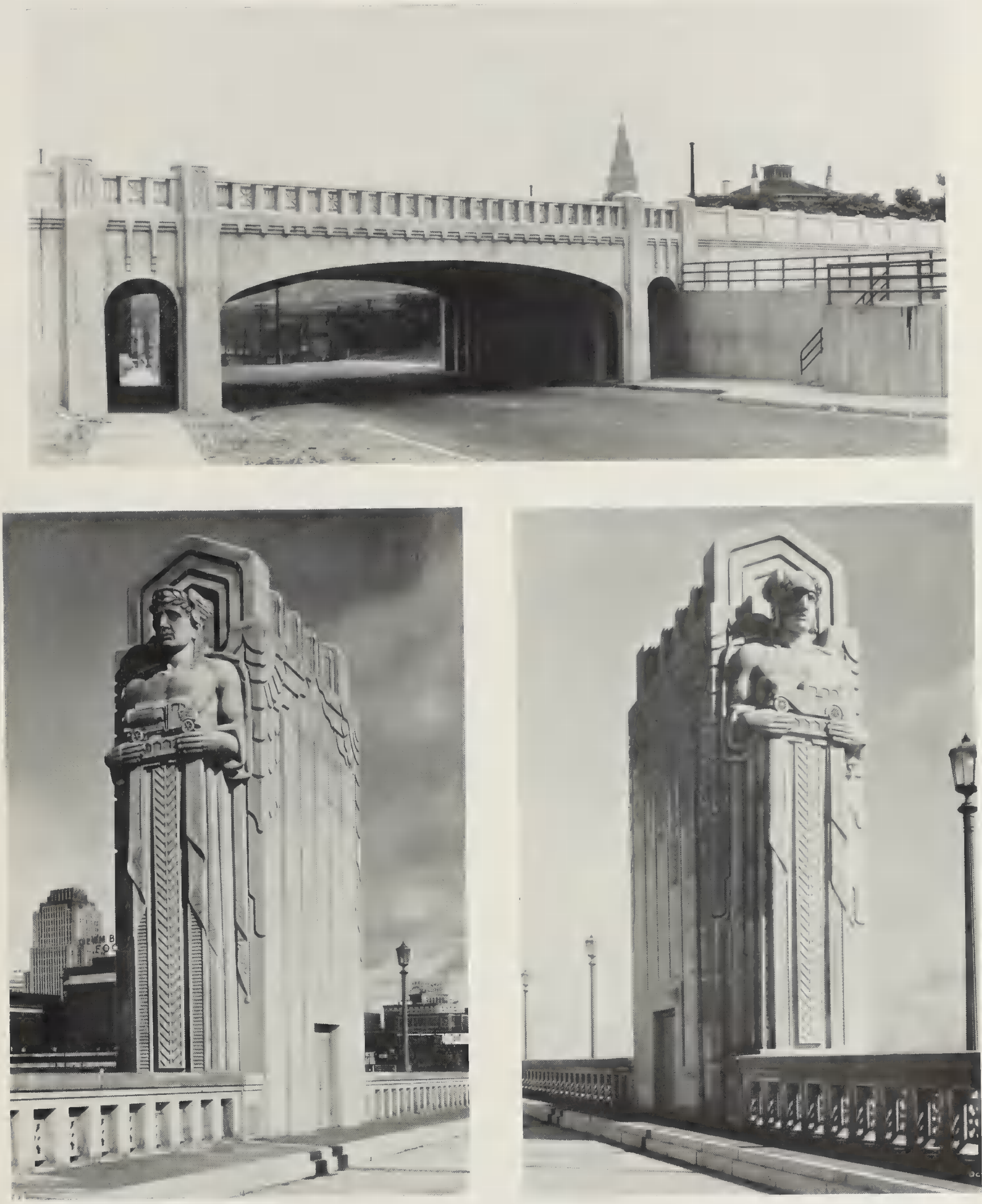
CLEVELAND, OHIO, LORAIN-CARNEGIE BRIDGE OVER CUYAHOGA RIVER VALLEY

This bridge, opened for traffic in November, 1932, received honorable mention by the American Institute of Steel Construction as one of the most beautiful bridges completed in that year. From southeast to northwest, Cleveland is traversed by the winding Cuyahoga River Valley which, while it provides a navigable channel for ships and the railroads with an effective entrance to the city, cuts it into two distinct districts so far as vehicular traffic is concerned. To provide crossings over the river and its wide valley, several bridges have been built, notably the Detroit-Superior Bridge near the lake front and the Central Viaduct to the south. The Lorain-Carnegie Bridge lies between the two mentioned and crosses the river at an elevation sufficient to clear shipping, a clearance of 93 feet being required by the U. S. War Department. It is 5,865 feet long, double deck, providing a 60 foot roadway and two 7 foot walks on the upper deck with room for two rapid transit tracks and two 18 foot trucking roadways on the lower deck when needed. The entire main structure is carried over the valley by steel trusses of the cantilever type, varying in span from 299 feet over the river to 132 feet at the ends, and supported upon concrete piers. The cantilever trusses vary from conventional outline in that the lower chords are curved to provide an arched appearance to the structure. It was found that the increased cost of curving these chords, over and above an irregular and broken outline, was very slight and fully warranted by the better appearance,—the side elevation of the bridge being in full view from the other viaducts and also from many of the principal office buildings of the city. For similar reasons, a concrete facia was carried from the tops of the piers to the underside of the coping. The parapets are of Berea sandstone for top and bottom rails and for posts, with cast aluminum panels for fillers.

The four massive pylons are embellished by two figures each, back to back, facing traffic in each direction. These huge figures, which are stylized to a marked degree in design, typify the spirit of progress in transportation. This progress relates to vehicular traffic and takes no account of pedestrians, as it is obvious that walking is much the same today as in the past, although less practised. These large figures hold in their hands the following vehicles represented in a conventionalized form, of course: Hay Rack, Covered Wagon, Stage Coach, Passenger Automobile and four types of present-day motor trucks illus-



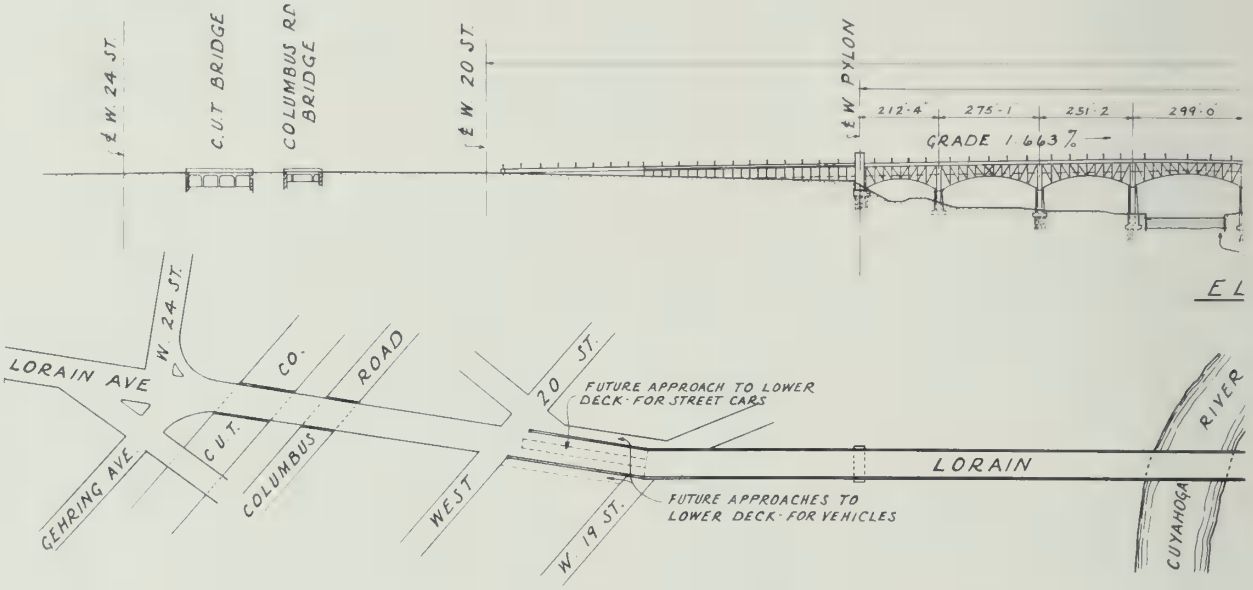
Figures 12, 13A, 13B. LORAIN-CARNEGIE BRIDGE WITH PYLONS, CLEVELAND, OHIO
Wilbur Watson and Associates, Engineers. Walker & Weeks, Architects. Henry Hering, Sculptor.

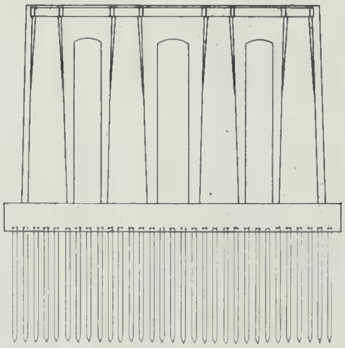


Figures 14, 15A, 15B. LORAIN-CARNEGIE BRIDGE WITH PYLONS, CLEVELAND, OHIO
Wilbur Watson and Associates, Engineers. Walker & Weeks, Architects. Henry Hering, Sculptor.

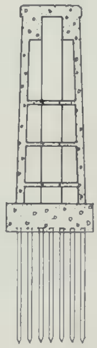
trating special purpose business transportation, all marking the trend of such vehicles at the date of the building of the bridge. These large figures are in the way of being Guardians of Traffic.

The bed of the Cuyahoga Valley is composed of glacial deposits of silt, sand and clay overlying the native shale to a depth of approximately 150 feet. The characteristics of this overburden vary greatly but in general cannot be relied upon to carry heavy loads. All of the piers of this bridge are founded upon piling:—concrete piles being used under all piers except those at the crossing of the river, which are founded upon timber piling. The footings for the river piers are carried down to an average depth of 38 feet below the river level. The river is navigable for ships drawing about 20 feet.



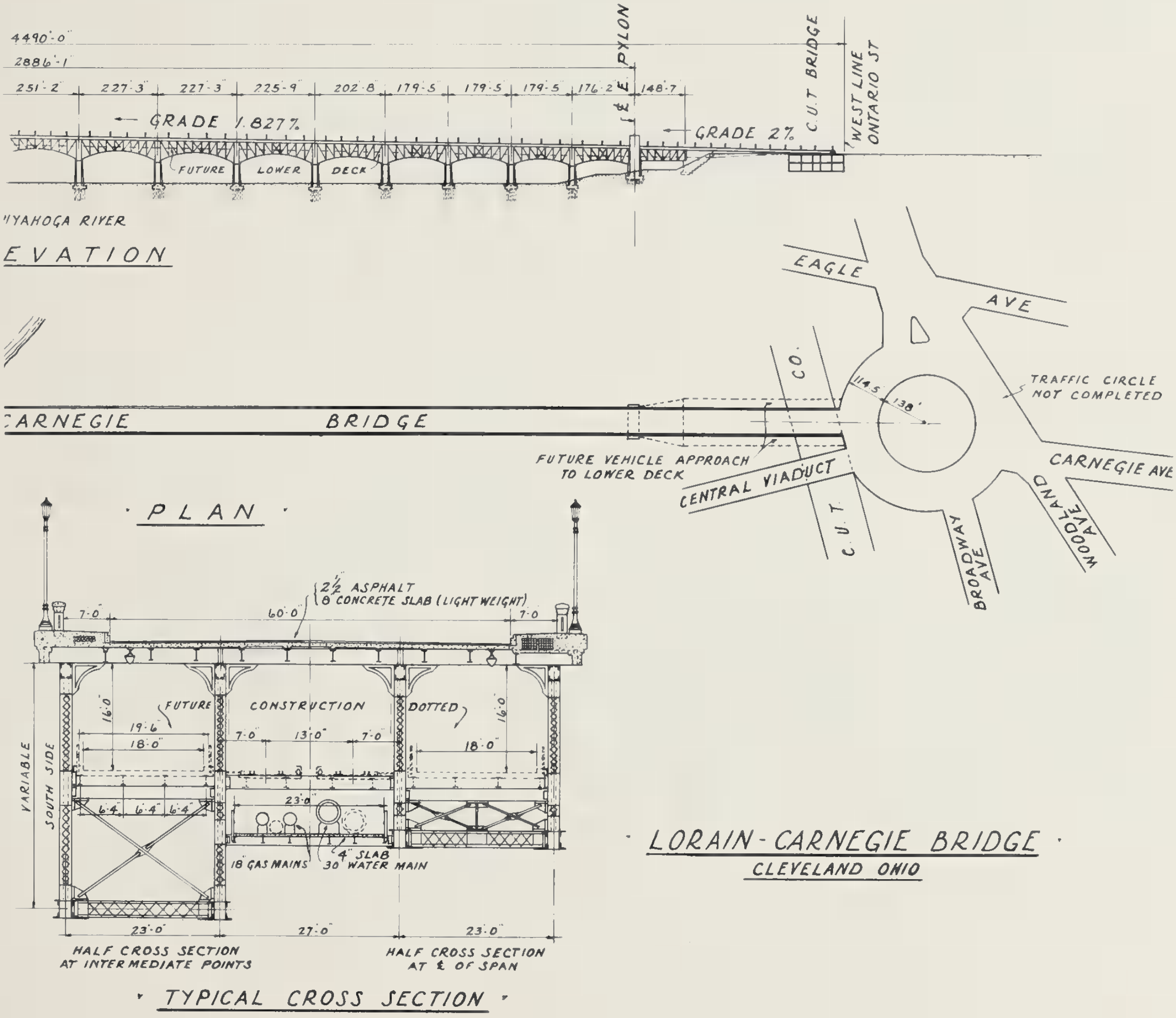


· ELEVATION OF TYPICAL PIER ·



· TYPICAL SECTION ·

Silicon steel was used for the main members of the trusses, and Haydite concrete for the 8-inch deck slab. The 3-inch wearing surface of asphalt is laid directly upon this roadway slab. The sidewalks are paved with native sandstone flagging 2 inches thick, laid on a ½-inch bed of asphalt mastic. The curbs are of granite, 17 inches high above the gutters, with a 4-inch step-back at a height of 10½ inches. Lighting standards are spaced about 60 feet apart and equipped with 6000-Lumen lamps in dome refractors so designed that they throw about 2/3 of the total light inward and downward. About 71,000 yards of concrete were used in this project and 13,000 tons of structural steel. The total cost was about four million dollars, exclusive of real estate and property damages.



LORAIN-CARNEGIE BRIDGE
CLEVELAND OHIO

This bridge was built by Cuyahoga County, under the direction of Fred R. Williams, County Surveyor, and the late A. M. Felgate, County Bridge Engineer, and was designed by Dr. Wilbur J. Watson in collaboration with F. R. Walker, Architect. The colossal figures on the pylons were designed by F. R. Walker and modeled by Henry Hering.

CLEVELAND, OHIO, LORAIN ROAD VIADUCT OVER ROCKY RIVER

This bridge received the first prize awarded by the American Institute of Steel Construction for bridges costing less than $1,000,000 completed during 1935. It was constructed by the State of Ohio, and because of its location spanning a scenic valley which is part of the beautiful Metropolitan Park System of Cleveland, particular attention was devoted to making it an attractive structure.

Structurally, it consists of four parabolic two-hinged arches of steel, two of 256 feet span, center to center of piers, and two unsymmetrical end spans of about 237 feet length. The height above the valley is about 130 feet; the roadway width is 40 feet, flanked by two 5-foot walks.

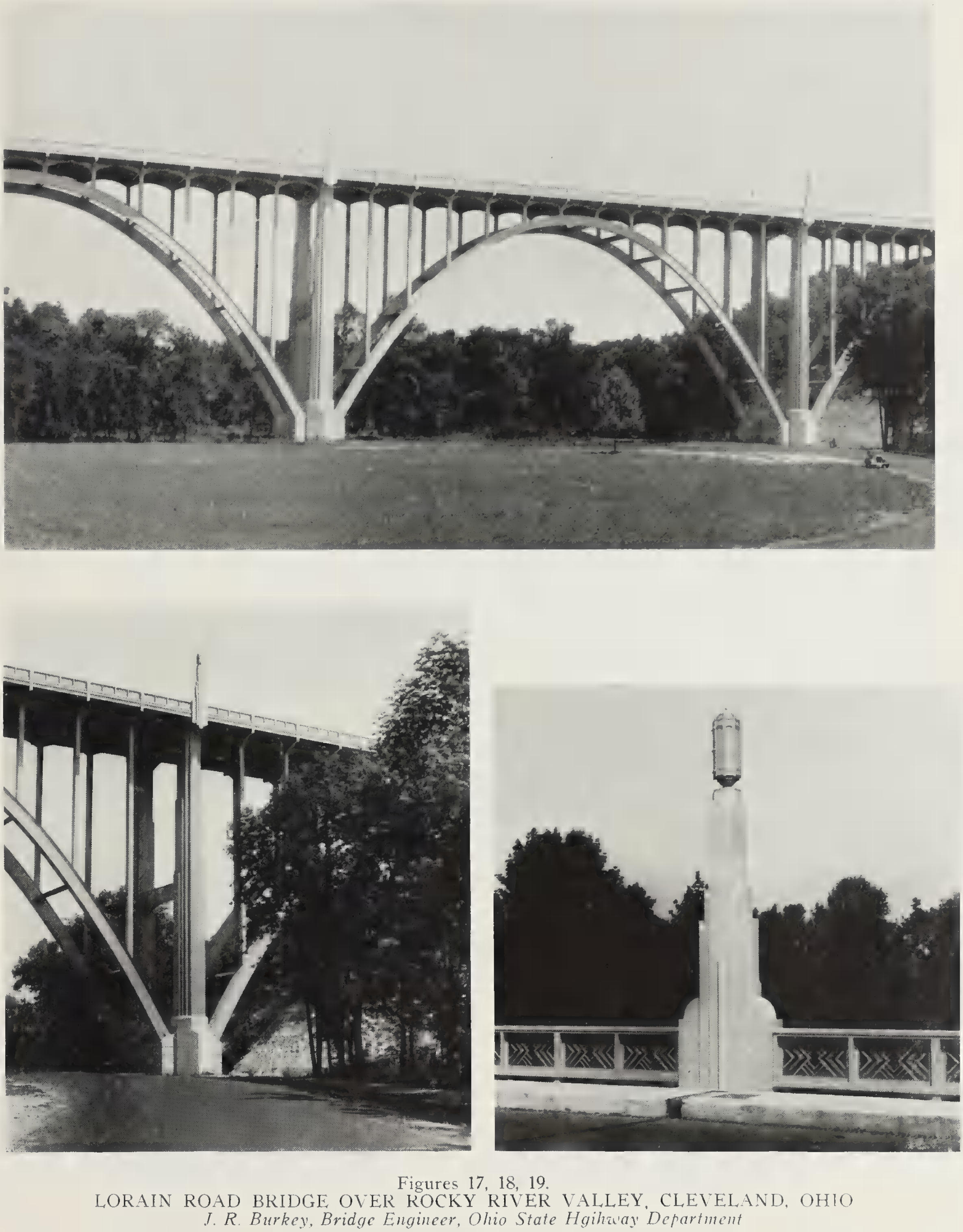
The plate girder arch ribs of uniform depth carry vertical posts without diagonal bracing. The architectural effect is produced by this omission of diagonals, resulting in the use of a minimum number of members, and these of the simplest possible outline, combined with tapering piers, and the use of a very unusual and striking color scheme,—a warm gray color for the masonry and a pale green for the steel, make it very effective in its park setting.

Considerable welding was done in order to eliminate rivet heads where from an architectural viewpoint they were considered to be objectionable and for the same reason a great deal of countersinking of rivet heads was also resorted to. The railing design of welded shapes and open malleable iron panels is also unique, but the question may well be raised as to why still more open designs of railings may not properly be used on bridges located in such beautiful settings as this one, in order that persons passing over them might enjoy the unusual scenery. Some engineers have argued that to do so is dangerous since most of the traffic is composed of automobiles, and the drivers should not have their attention diverted by looking at beautiful views. Safety first.

Altogether, this structure reflects great credit upon its designers,—the bridge engineers of the Ohio State Highway Department, of which J. R. Burkey is Chief Engineer and W. H. Rabe, Chief Designer.

COLOGNE-MUELHEIM BRIDGE, GERMANY

This bridge is the first to cross the Rhine in a single span and is the largest cable suspension span in Europe. The architectural treatment of the structure lies in expression of structural principles and achievement of decorative effect by an outline of the greatest simplicity.



Figures 17, 18, 19.
LORAIN ROAD BRIDGE OVER ROCKY RIVER VALLEY, CLEVELAND, OHIO
J. R. Burkey, Bridge Engineer, Ohio State Hgihway Department

The main span is 1,032 feet 5½ inches in length, with unloaded anchor spans of 298 feet 7¾ inches each. The cables are of the twisted wire rope type, each consisting of 37 ropes, forming a hexagon approximately 22 inches in diameter. The ropes are composed of inner layers of round wires, surrounded by layers of wedge shaped wire, and finally by layers of specially shaped interlocking wires, all of cast steel with a strength of from 192,000 to 213,500 pounds per square inch.

The towers are extremely simple, almost stark, in outline, constructed of silicon steel and provided with hinges at the bases. The roadway is 56 feet

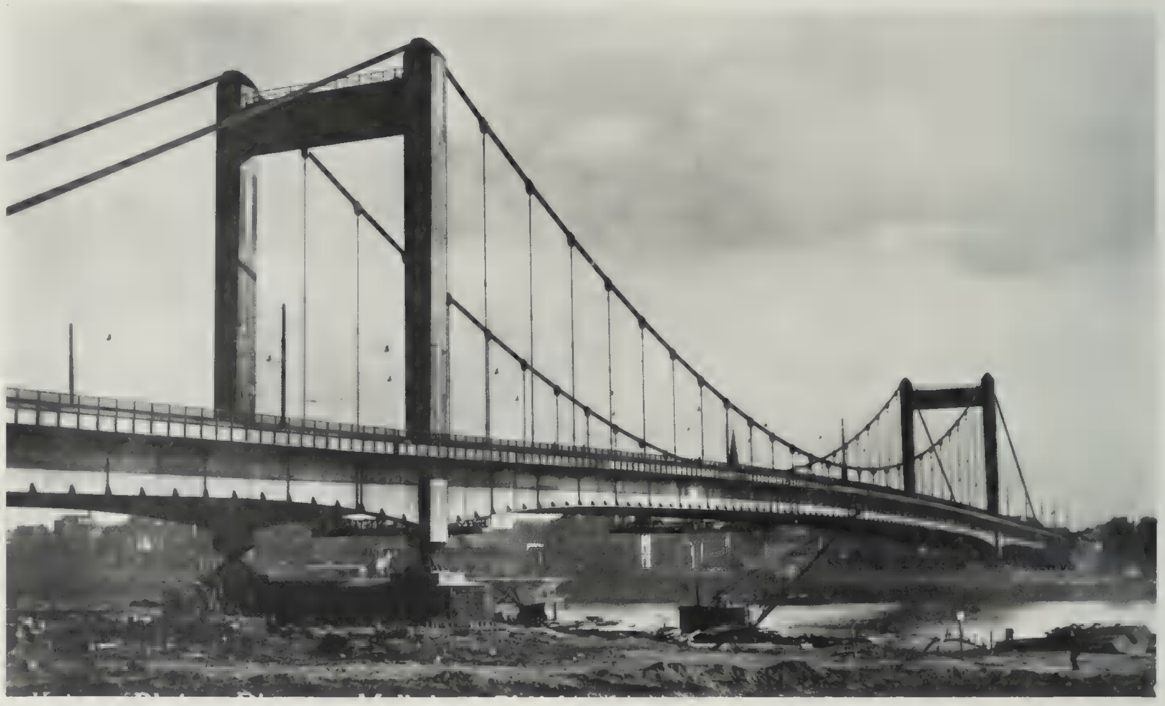
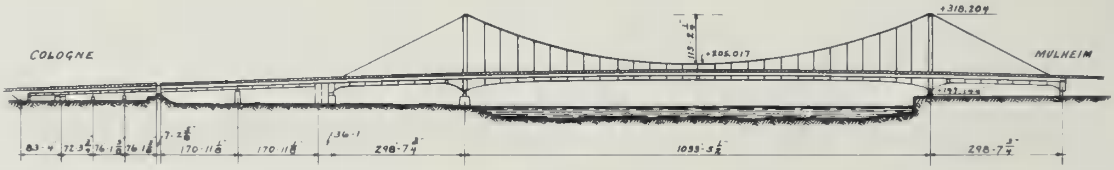


Figure 20. THE COLOGNE-MUELHEIM BRIDGE OVER THE RHINE, COLOGNE, GERMANY
Karl Mohringer, Engineer—1929



· ELEVATION · OF · COLOGNE - MULHEIM · SUSPENSION · BRIDGE ·
COLOGNE GERMANY

5¼ inches. The footwalks are 11 feet 5¾ inches wide and placed outside of the stiffening trusses. This bridge is of the self-anchored type, in which the horizontal reaction of the cables is resisted by the stiffening girders and the vertical reaction by counterweights. The pavement surface is 4-inch wood blocks.

COLUMBIA, PENNSYLVANIA, BRIDGE OVER THE SUSQUEHANNA RIVER

This is a reinforced concrete arch bridge, 7,374 feet in length and comprising 28 spans of 185 feet of the open spandrel type. It was constructed in 1929 by the State Highway Department of Pennsylvania to replace a steel structure built in 1897, which in turn superseded an historic covered timber bridge. This bridge carries U. S. route 30—the Lincoln Highway, over the Susquehanna. Although located at a spot of great natural beauty and of historic interest, this bridge has solid and high parapets which shut off all view of the landscape as effectually as did its ancestral covered wooden bridge. The designing engineer was J. B. Long.

CROWN POINT, NEW YORK, BRIDGE OVER LAKE CHAMPLAIN

A bridge over Lake Champlain, the first to be built across this historic waterway, was awarded a prize by the American Institute of Steel Construction as being one of the three most beautiful bridges erected in the year 1929. It is fortunate in having a quite unusual and beautiful setting as well as an historic background, for the west approach is located at the Crown Point Reservation containing the ruins of Fort St. Frederick and Fort Amherst. A fine view of the bridge is to be had from the nearby Champlain Memorial Lighthouse.

From an engineering standpoint, this structure is of interest also for its use of continuous trusses of graceful outline, the main channel span of 434 feet and the two flanking spans of 290 feet each, forming a continuous three-span structure. The total length of bridge is 2,190 feet between abutments and the cost was about one million dollars, sixty per cent of which is allocated to the State of New York and forty per cent to Vermont.

The type of continuous truss introduced here has, as one of its practical advantages, that of allowing easy erection by the cantilever method, and it is also quite economical of material. Unquestionably it is pleasing in appearance.

The maximum roadway grades are 5½ per cent. The main piers are founded in over 90 feet of water by the open cofferdam methods, using steel sheet-piling—at that time the record depth attained by that method—the sheet piles being 98 feet in length. The roadway width is 24 feet and sidewalks are 2½ feet wide, placed between the curbs and the trusses—in this case commonly called "Refuge Walks" which enable the rare pedestrian to get out of the way of an automobile. The vertical clearance for boats is 90 feet.

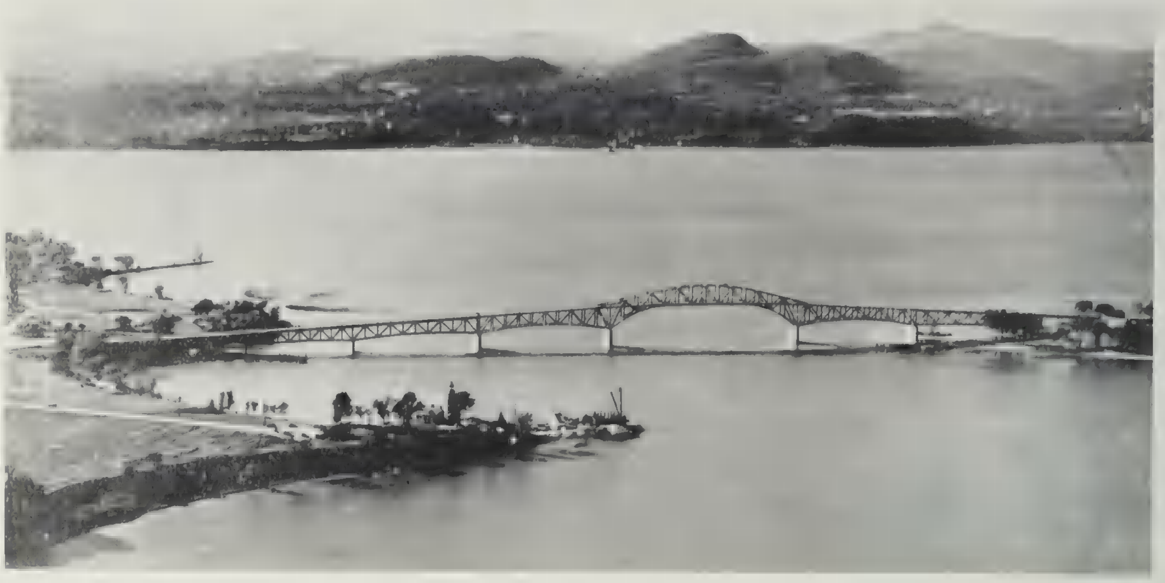


Photo by Fairchild Aerial Service

Figure 22. BRIDGE ACROSS LAKE CHAMPLAIN, CROWN POINT, NEW YORK
Fay, Spofford & Thorndike, Engineers

The bridge was opened on August 26, 1929, and forms a connecting link between main highway routes. The project was in charge of a board of commissioners representing the two states, and tolls are charged, which will be abolished when the cost of the project shall have been amortised, estimated at thirty years. The bridge will doubtless be freed in much less time than this.

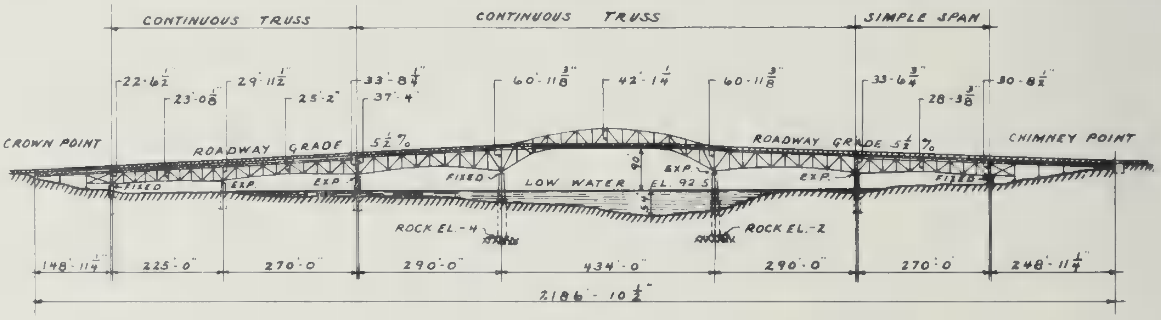


Figure 23. • ELEVATION • OF • LAKE • CHAMPLAIN • BRIDGE •

DETROIT, MICHIGAN, AMBASSADOR BRIDGE OVER THE DETROIT RIVER

This is a toll bridge of the suspension type built by private corporations—the Detroit International Bridge Company and the Canadian Transit Company—and was opened for traffic on November 15, 1929. Financing involved the issuance of twelve million dollars of first mortgage bonds and eight millions of debentures.

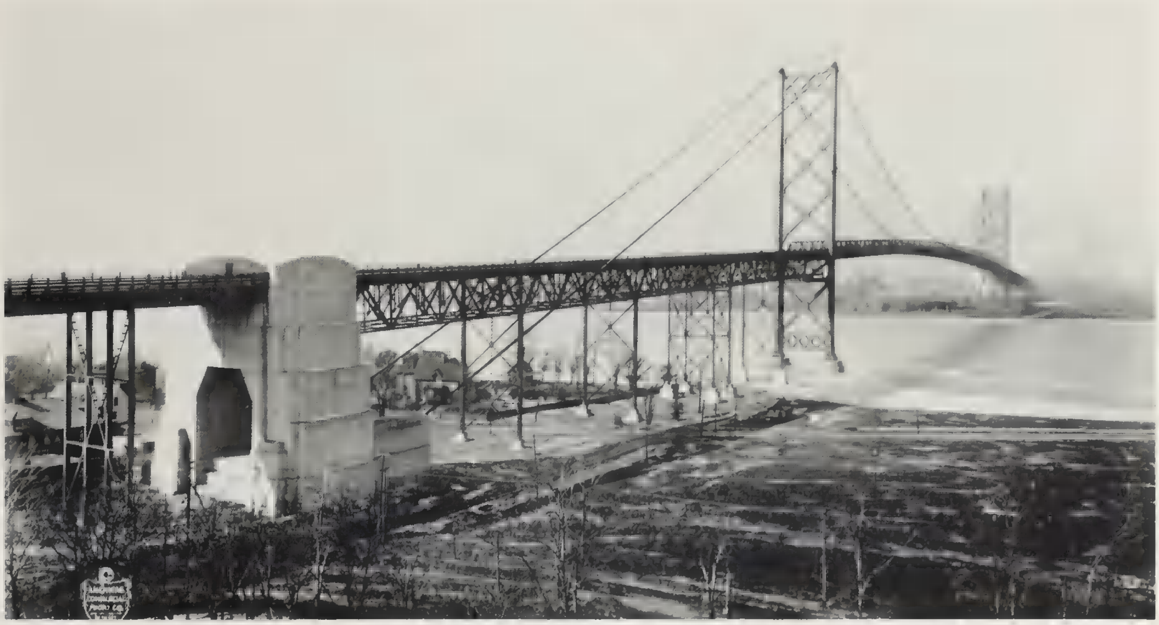


Figure 23. THE AMBASSADOR BRIDGE OVER THE DETROIT RIVER, DETROIT, MICHIGAN

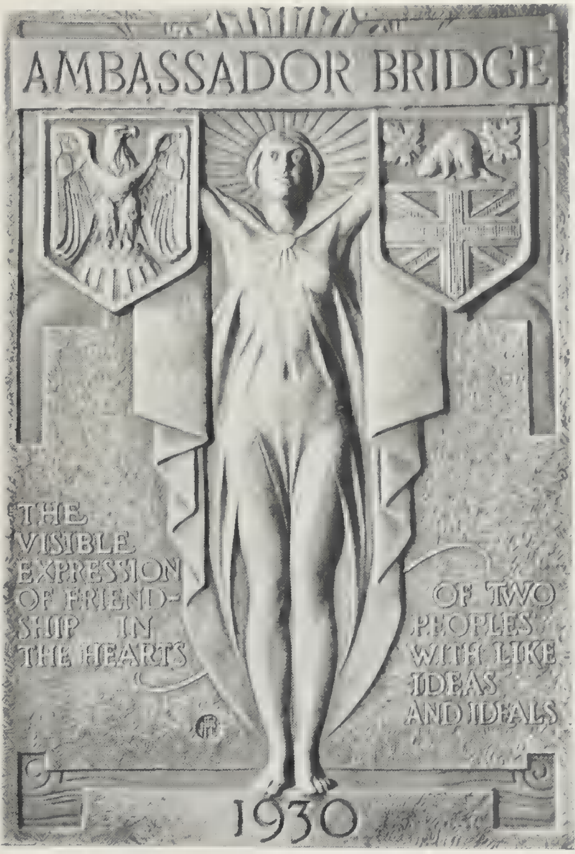

AMBASSADOR BRIDGE
THE VISIBLE EXPRESSION OF FRIENDSHIP IN THE HEARTS
OF TWO PEOPLES WITH LIKE IDEAS AND IDEALS
1930

Figure 25. SOUVENIR PLAQUE
The Ambassador Bridge over the Detroit River, Detroit, Michigan

Physical Data:

Length of main suspended span—1,850 feet.
Cables—2.
Roadway width 47 feet, 1 sidewalk 8 feet wide.
Height of main towers—363 feet.
Vertical clearance—152 feet.
Maximum approach grades—5 per cent.
Total length approximately 9,200 feet from entrance to entrance.
The roadway slab is of reinforced concrete 6 inches thick with 2½ inch asphalt pavement.

It will be noted from the photograph showing the general elevation of the bridge that the side spans are supported from the ground and not suspended from the cables as is the case with the George Washington Bridge and the Philadelphia-Camden Bridge. While not so pleasing to the observer this device reduces the horizontal tension on the backstays and is of advantage where the anchorage conditions are difficult, as they were here. The most difficult engineering problem encountered was involved in the anchorages, on account of the great depth to rock through wet clay and quicksand—the rock a hard level limestone lying about 105 feet below the river level.

Each of the main piers consists of two 38-foot diameter cylinders with 18-foot diameter hollow shafts, and the two anchorages consist of two rectangular blocks 100 feet by 225 feet in plan, with four working shafts 10½ by 16 feet. All are of reinforced concrete, and sunk by open dredging through sand and clay as far as possible and then completed under air pressure. The rock was overlaid by a 10-foot layer of hardpan that could not be excavated by the buckets, necessitating the application of air. This bridge originally used heat-treated wire for the main cables, and experienced the same difficulty that appeared on the Mt. Hope Bridge, necessitating the dismantling of the superstructure before completion and the replacing of the cables, using untreated cold drawn wire. This wire failure, fortunately discovered before the completion of the bridge, is more fully discussed in the description of the bridge at Mt. Hope, Rhode Island.

All international bridges such as this require expensive terminal facilities for accommodation of customs and immigration officials, and the inspection of vehicles. On the Ambassador Bridge each terminal covers a full city block, providing room for fanning out traffic into twenty-six lanes for inspection, and parking facilities for holding vehicles detained for various reasons. These facilities provide for the examination of some 4,000 touring cars per hour, and the service buildings in connection with them provide rooms for inspection, medical attention, detention under guard, garage space, retiring rooms, and administrative offices.

Personnel:

This bridge was designed by the general contractors, The McClintic-Marshall Company, Jonathan Jones, Chief Engineer, who retained as consultants Moran, Maurice and Proctor on foundations; Leon S. Moisseiff on the main span suspended structure; Smith, Hinchman and Grylls as architects; and Monsarrat & Pratley, consulting engineers of Montreal. Modjeski & Chase served as consultants for the Detroit International Bridge Company.

DENMARK, BRIDGE OVER THE LITTLE BELT

This is the first of a number of bridges planned by the State of Denmark to connect its various islands with the mainland, this one connecting Jutland with the island of Funen.

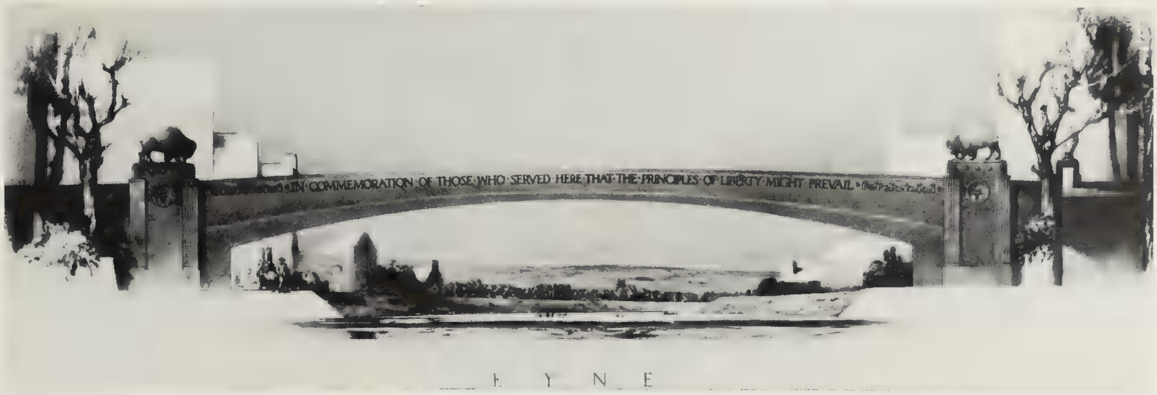
It is a cantilever type structure composed of five spans varying in length from 451 feet to 722 feet, designed so that the upper chords form a uniform curve from end to end. It carries a double track railway and an 18 foot 5 inch roadway.

An unique feature consists in the type of steel caissons used, which were built in shallow water in an upside down position, towed to the site, turned over and sunk in 130 feet of water. The walls of the caissons are composed of a series of steel cylinders, through which open dredging was carried on until the caissons were seated 23 feet into the clay, when the pipes were sealed with underwater concrete, the caissons emptied, the working chamber opened, and the work completed in the dry without the use of air pressure.

This bridge was completed on May 14, 1935, at a cost of about $5,300,000, after designs by Prof. Auker Engelund, engineer for the Danish State Railways.

EYNE, BELGIUM, MEMORIAL BRIDGE

This little bridge was erected in 1929 by the State of Ohio as a memorial to her heroic dead who fell in this neighborhood during the last days of the World


IN COMMEMORATION OF THOSE WHO SERVED HERE THAT THE PRINCIPLES OF LIBERTY MIGHT PREVAIL
EYNE

Photo, Courtesy The Ernst Studio Co.

Figure 27. MEMORIAL BRIDGE OVER THE SCHELDT RIVER, EYNE, BELGIUM
Walker & Weeks, Architects

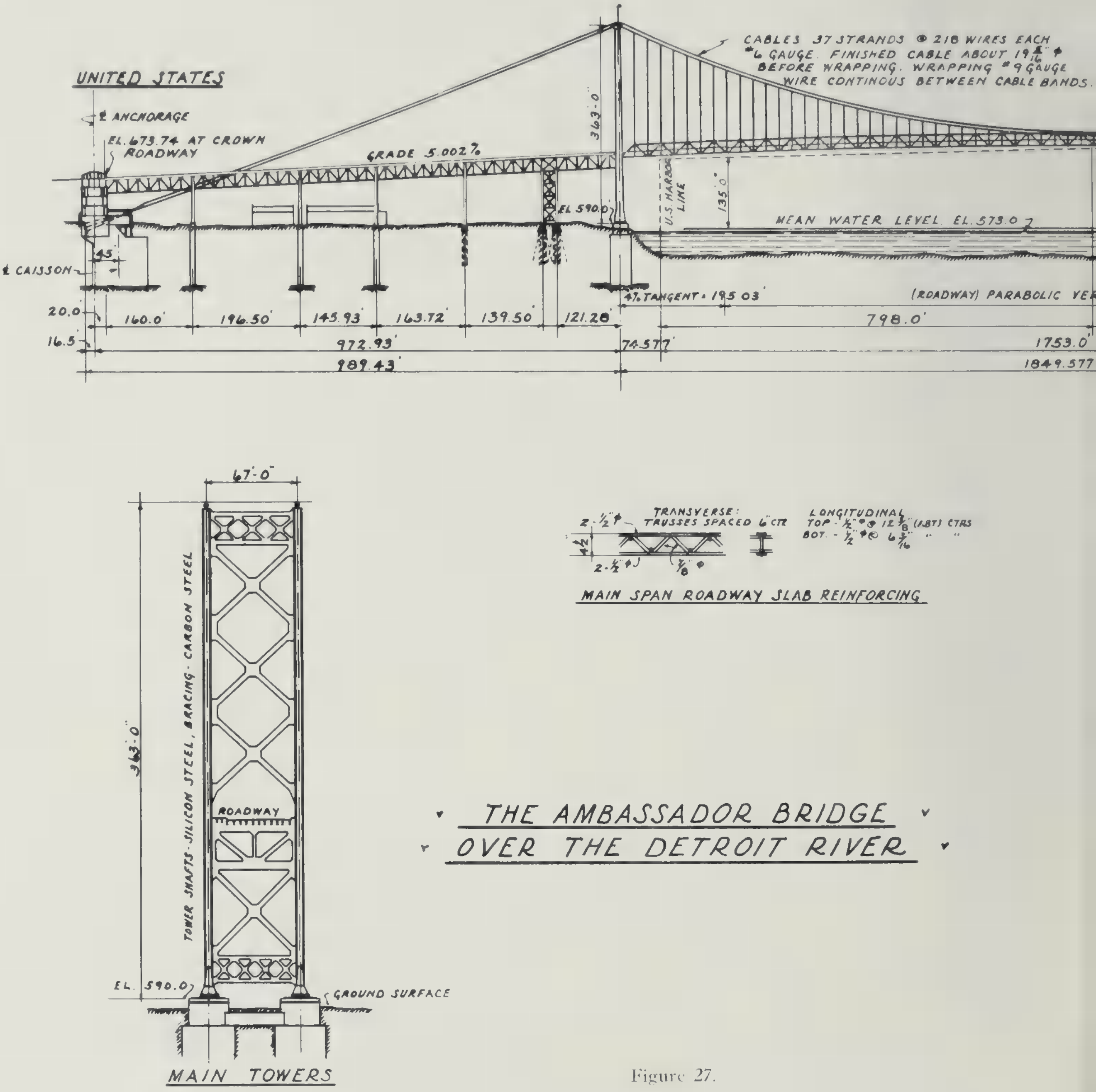
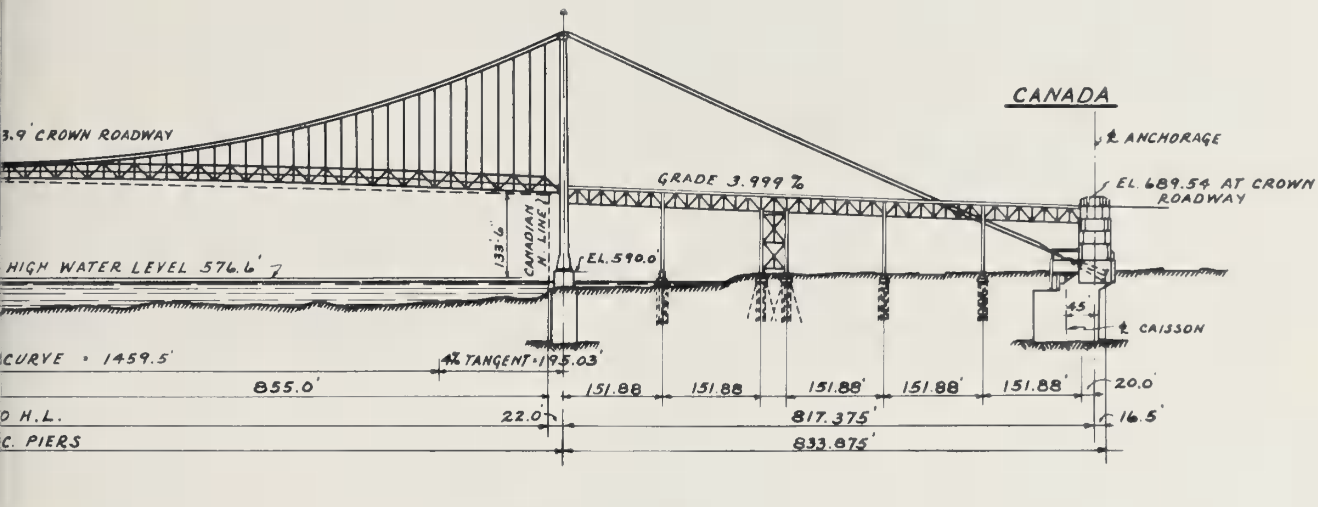
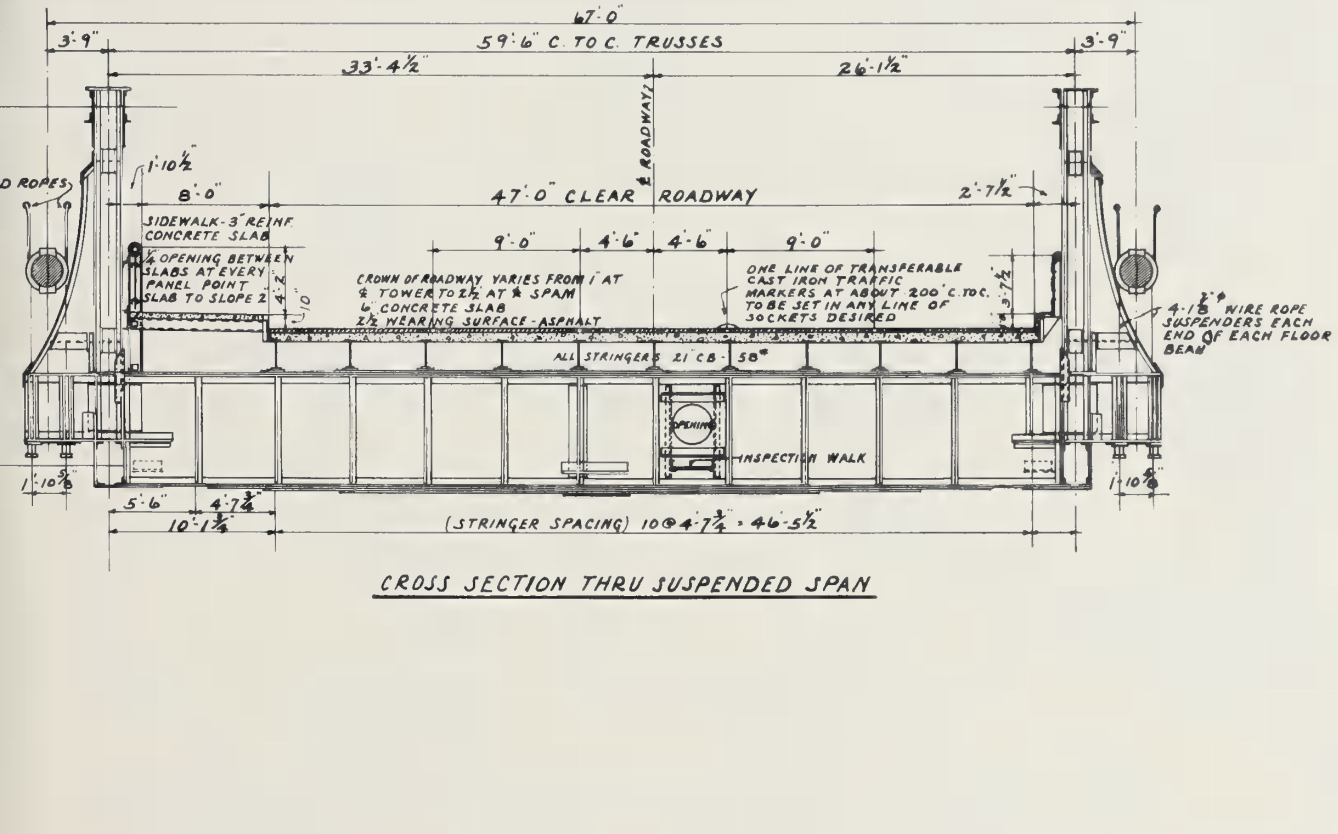

UNITED STATES
℄ ANCHORAGE
EL. 673.74 AT CROWN ROADWAY
GRADE 5.002%
363'-0"
CABLES 37 STRANDS @ 218 WIRES EACH #6 GAUGE. FINISHED CABLE ABOUT 19 1/16" ϕ BEFORE WRAPPING. WRAPPING #9 GAUGE WIRE CONTINOUS BETWEEN CABLE BANDS.
U.S. HARBOR LINE
135'-0"
EL. 590.0
MEAN WATER LEVEL EL. 573.0
℄ CAISSON
45
4% TANGENT = 195.03'
(ROADWAY) PARABOLIC VE
20.0'
16.5'
160.0'
196.50'
145.93'
163.72'
139.50'
121.28'
798.0'
972.93'
74.577'
1753.0'
989.43'
1849.577
67'-0"
363'-0"
TOWER SHAFTS - SILICON STEEL, BRACING - CARBON STEEL
ROADWAY
EL. 590.0
GROUND SURFACE
MAIN TOWERS
TRANSVERSE: TRUSSES SPACED 6" CTR
2-1/2" ϕ
4 1/2
2-1/2" ϕ
7/8" ϕ
LONGITUDINAL TOP - 1/2" ϕ @ 12 1/8" (ABT) CTRS
BOT. - 1/2" ϕ @ 6 1/16" " "
MAIN SPAN ROADWAY SLAB REINFORCING
THE AMBASSADOR BRIDGE
OVER THE DETROIT RIVER

Figure 27.




67'-0"
3'-9"
59'-6" C. TO C. TRUSSES
3'-9"
33'-4½"
26'-1½"
℄ ROADWAY
D ROPES
1'-10½"
8'-0"
47'-0" CLEAR ROADWAY
2'-7½"
SIDEWALK-3" REINF. CONCRETE SLAB
¼ OPENING BETWEEN SLABS AT EVERY PANEL POINT SLAB TO SLOPE 2
4'-2
10"
9'-0"
4'-6"
4'-6"
9'-0"
CROWN OF ROADWAY VARIES FROM 1" AT ℄ TOWER TO 2½" AT ℄ SPAN
6" CONCRETE SLAB
2½" WEARING SURFACE - ASPHALT
ONE LINE OF TRANSFERABLE CAST IRON TRAFFIC MARKERS AT ABOUT 200' C. TO C. TO BE SET IN ANY LINE OF SOCKETS DESIRED
3'-7½"
4-1⅞" WIRE ROPE SUSPENDERS EACH END OF EACH FLOOR BEAM
ALL STRINGERS 21" CB - 58#
OPENING
INSPECTION WALK
1'-10⅝"
1'-10⅝"
5'-6"
4'-7¾"
10'-1¾"
(STRINGER SPACING) 10 @ 4'-7¾" = 46'-5½"

CROSS SECTION THRU SUSPENDED SPAN

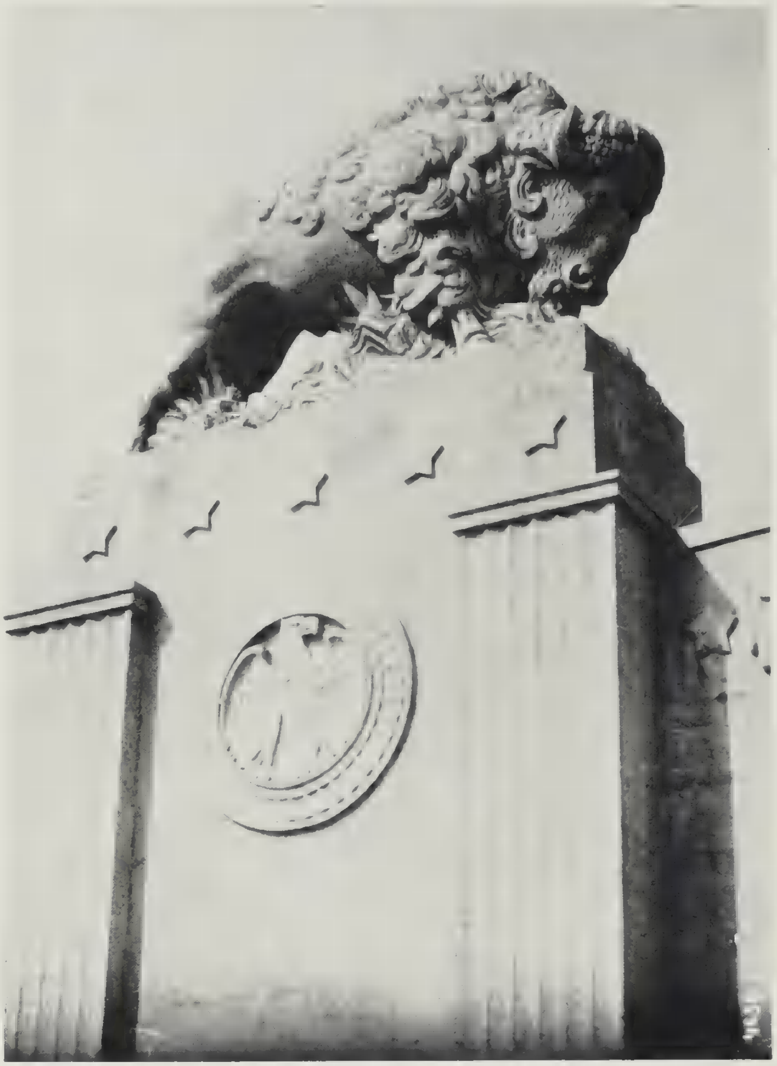


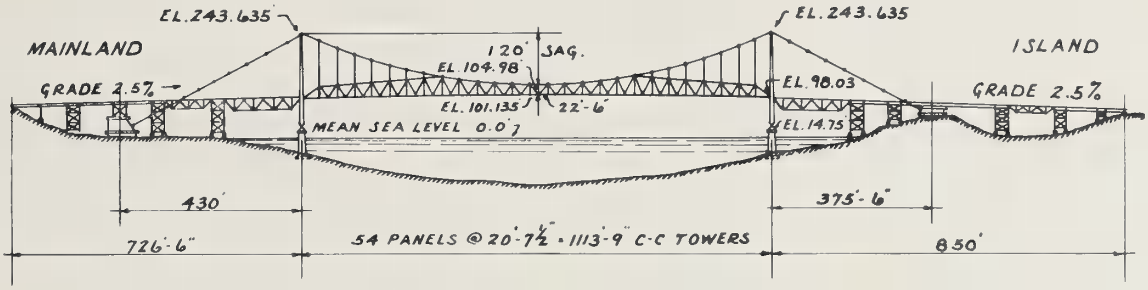
Figure 28. PYLON MEMORIAL BRIDGE OVER THE SCHEDLT RIVER, EYNE, BELGIUM
Walker & Weeks, Architects

War. It spans the Scheldt River near the village of Eyne. The design is by Walker & Weeks, architects of Cleveland, Ohio, and the buffaloes that surmount the four pylons were cast in cement molds after models by Moreau-Vauthier, Paris sculptor. This bridge is structurally a reinforced cantilever of about 120 feet span.

FLORIANAPOLIS, BRAZIL, SUSPENSION BRIDGE

The distinguishing features of this bridge are the peculiar form of stiffening trusses, the use of eye-bar cables and the introduction of hinges at the base of the towers.

The eye-bars for the cables are of heat treated steel providing material with an ultimate strength of 105,000 pounds per square inch and an elastic limit of 75,000 pounds.



ELEVATION OF BRIDGE AT FLORIANOPLIS, BRAZIL

Figure 29.

This bridge, with its suspended span of 1,113 feet 9 inches center to center of towers, is the longest of its kind in the world and carries a 28-foot roadway, a meter gage railway and a 9-foot walk.

It was completed in 1926, after designs by Robinson and Steinman of New York, and connects the island of Santa Catherina with the mainland.

FREEPORT, ILLINOIS, KRAPE PARK BRIDGE

This exquisite small structure, built in 1934, has a clear span of 70 feet, designed as a rigid frame in reinforced concrete. From both an engineering and an architectural viewpoint it expresses the most recent thought in the design of artistic small bridges.

GRAND CANYON, ARIZONA, KAIBAB TRAIL BRIDGE

Located in Grand Canyon National Park where the Kaibab Trail crosses the Colorado River just above the mouth of Bright Angel Creek, and completed in 1929, this suspension bridge, 500 feet long between anchorages, had to be built with members not over 10 feet long and weighing less than 200 pounds each, necessitated by the difficulties of pack trail transportation. The roadway width is 5 feet. This unique project was carried out under the direction of Frank A. Kittredge, Chief Engineer, National Park Service.

GRAND CANYON, ARIZONA, BRIDGE OVER THE COLORADO RIVER, 1928

A deck spandrel-braced steel arch 618 feet center to center end pins, and 833 feet long over all, spanning the river at Lee's Ferry above the Grand Canyon National Park. It is similar in appearance to the upper arch at Niagara Falls. Engineer—Ralph A. Hoffman, Bridge Engineer, Arizona Highway Department. L. C. Lashment, Designing Engineer.

GRAND-MERE, QUEBEC, 1929

A suspension bridge with a main span of 949 feet of the rope-strand type of cables and straight backstays. The roadway is 18 feet wide, paved with 6 inch laminated redwood plank covered with 1¾ inches of asphalt. Robinson and Steinman were the consulting engineers.

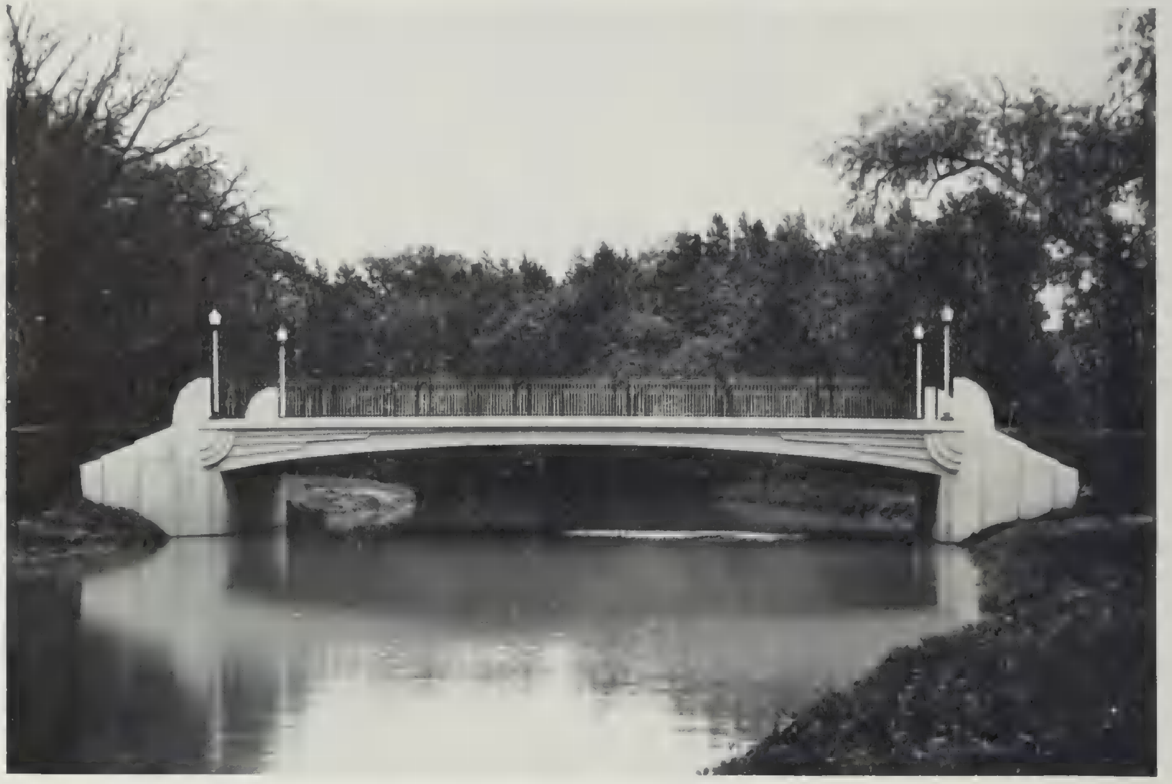
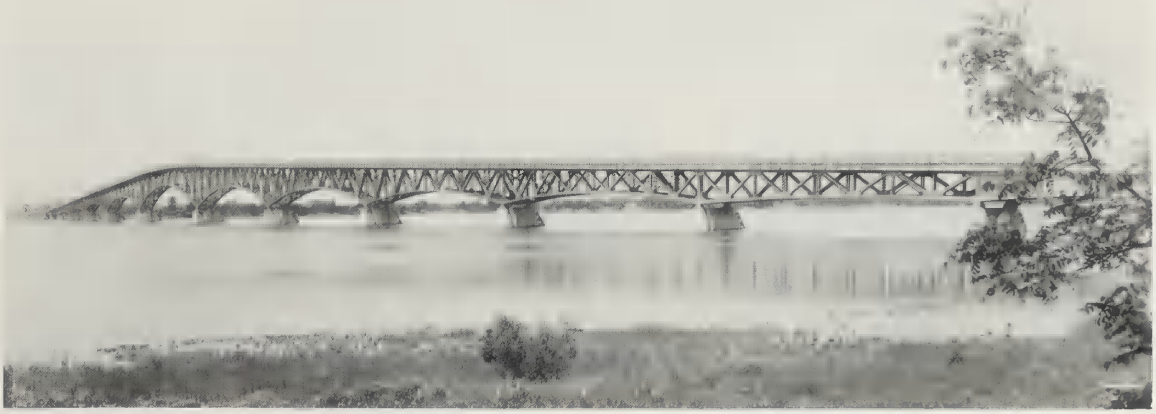


Figure 30. KRAPE PARK BRIDGE, FREEPORT, ILLINOIS
Mogens Ipsen, Engineer *R. R. Eastman, Architectural Assistant*

GRAND ISLAND, NEW YORK, NIAGARA RIVER BRIDGES

The project of bridging the Niagara River between Grand Island and the mainland has been under consideration for many decades and was realized in 1935, when two handsome steel bridges, constructed at a cost of about two and three-quarter million dollars, were opened for traffic. The North Bridge was awarded first prize by the Jury of Awards of the American Institute of Steel Construction for being the most beautiful bridge of its class completed in that year. It consists of a series of cantilever spans for the main structure, all of the deck type, the longest, or channel span, being 500 feet in length, and it carries a 24-foot roadway and a 6-foot walk.

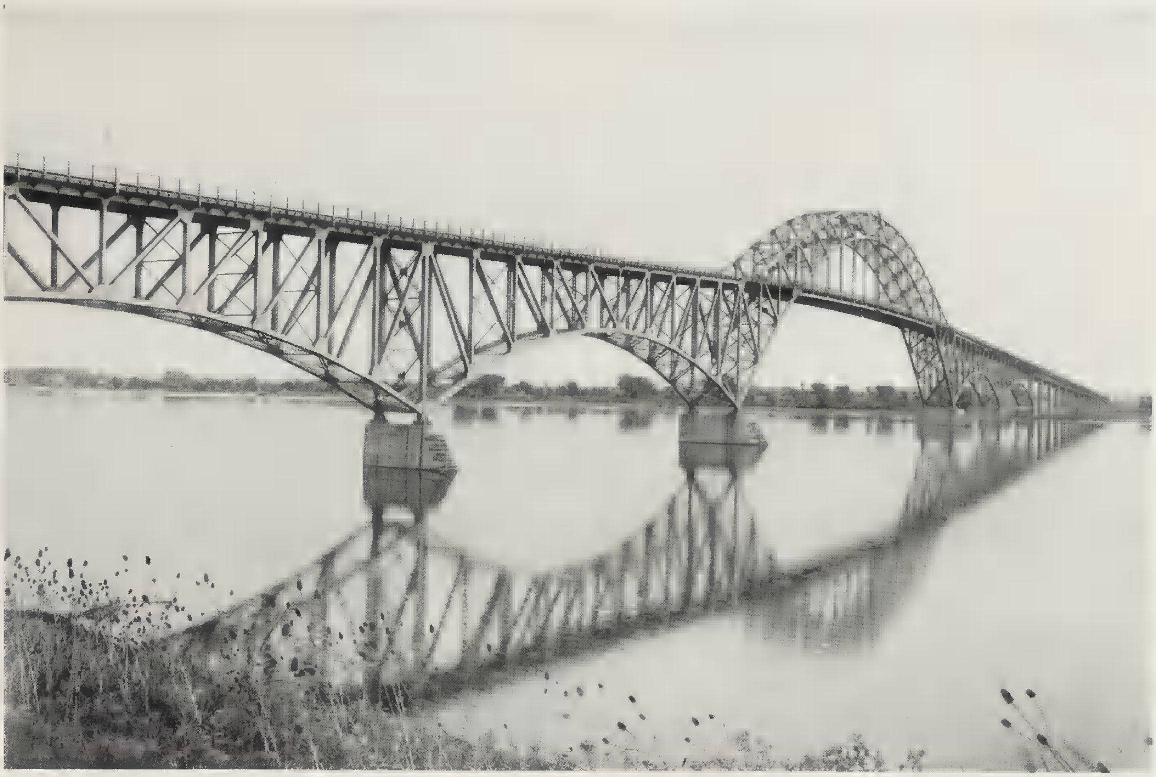
The South Bridge is, perhaps, even more beautiful than the North, consisting of a 600-foot channel span of the overhead type, flanked by arched cantilever deck spans. Quoting Dr. Hardesty, "The channel span of the South Bridge is perhaps the most novel feature of the two structures. The 400-foot suspended span is a true tied-arch carried on the ends of the two 100-foot cantilevers. While the entire 600-foot span has the outline of a spandrel-braced arch rather than of an ordinary cantilever bridge; nevertheless the proportions are at all points correct for the stresses of the cantilever structure."



Photos, Courtesy Hare, Buffalo, New York

Figures 31A and 31B. BRIDGES OVER NIAGARA RIVER, GRAND ISLAND, N. Y.

Waddell & Hardesty, Designing Engineers



HARRISBURG, PENNSYLVANIA, MARKET STREET BRIDGE OVER THE SUSQUEHANNA RIVER

This toll bridge across the Susquehanna on the line of Harrisburg's main street, has served as the main highway bridge over the river for a long time. It consists of two parts, separated by an island in the river, each part comprising some 16 spans of 88½ feet. The structure was rebuilt in 1904, using through type plate girders on stone masonry abutments. By 1927 the traffic had practically quadrupled and it became necessary to increase the width of the roadway. This was accomplished by lengthening the old piers to about twice their original dimension, using concrete with stone facing, and replacing the steel superstructure with concrete arches also faced with stone. This was done for one channel only, the steel superstructure from this half of the bridge being used to provide an additional roadway for the other half, thus doubling the roadway capacity of the bridge. The new bridge has a 40-foot roadway and two 6-foot walks. Ralph Modjeski and Frank M. Masters were the engineers, ably assisted by Paul P. Cret, architect. The photograph is intended to show the architect's treatment of the architectural features involved in the reconstruction of this historic bridge and the treatment of the Harrisburg Approach Plaza.

HARRISBURG, PENNSYLVANIA, SOLDIERS & SAILORS MEMORIAL BRIDGE

This monumental structure spans the tracks of the Pennsylvania Railroad and forms a principal approach to the magnificent Capitol buildings of the great State of Pennsylvania. The location demanded a structure that would harmonize with its surroundings, and the requirement was well met by the construction of two huge pylons supporting eagles of colossal size, placed at the entrance to the bridge from a spacious plaza adjacent to the Capitol grounds. This bridge was erected at a cost of nearly four million dollars.

The architects were Sidney Ross and William Gehron, who also collaborated in the design of the Veterans Memorial Bridge at Rochester and were awarded a medal in recognition of their work on these two bridges by the Architectural League of New York. Frank St. Clair, Jr., was Chief Engineer of Construction for the Department of Property and Supplies. The eagles on the top of the pylons were executed by Lee Lawrie, sculptor.

KOBLENZ, GERMANY, THE ADOLPH HITLER BRIDGE OVER THE MOSELLE RIVER

The Adolph Hitler Bridge over the Moselle at Koblenz, Germany, completed in 1934, is distinguished by comprising the flattest concrete arch in the world: with a span 382.7 feet; a rise of only 26.6 feet, and radius of arc of 577.4 feet. The ratio of rise to span is therefore about 1 to 14.4 and, by way of comparison, the corresponding ratio for the Alexander III Bridge at Paris, a cast steel arch world-famous for its flatness, is 1 to 17. However, the ratio of rise to span of

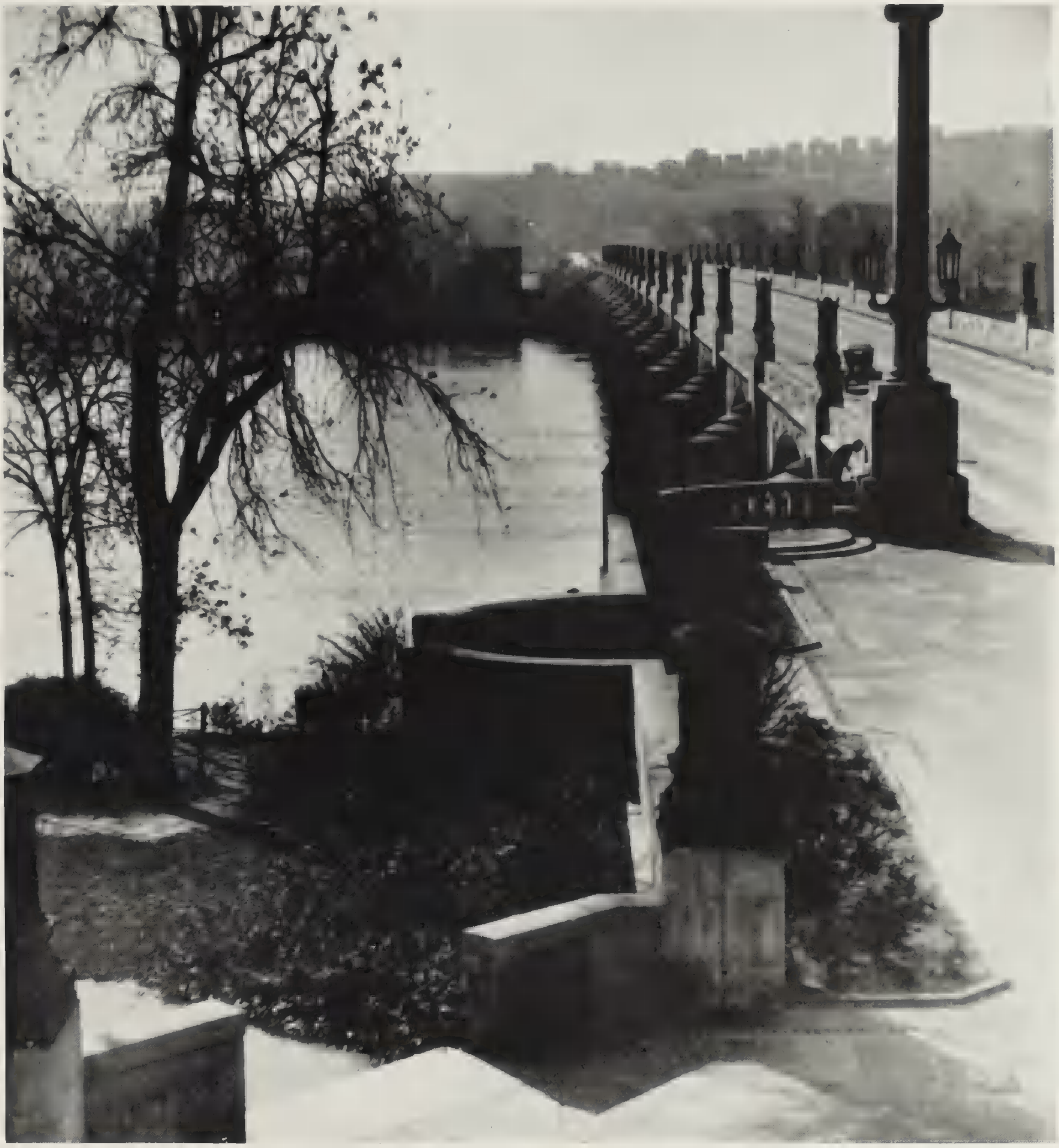
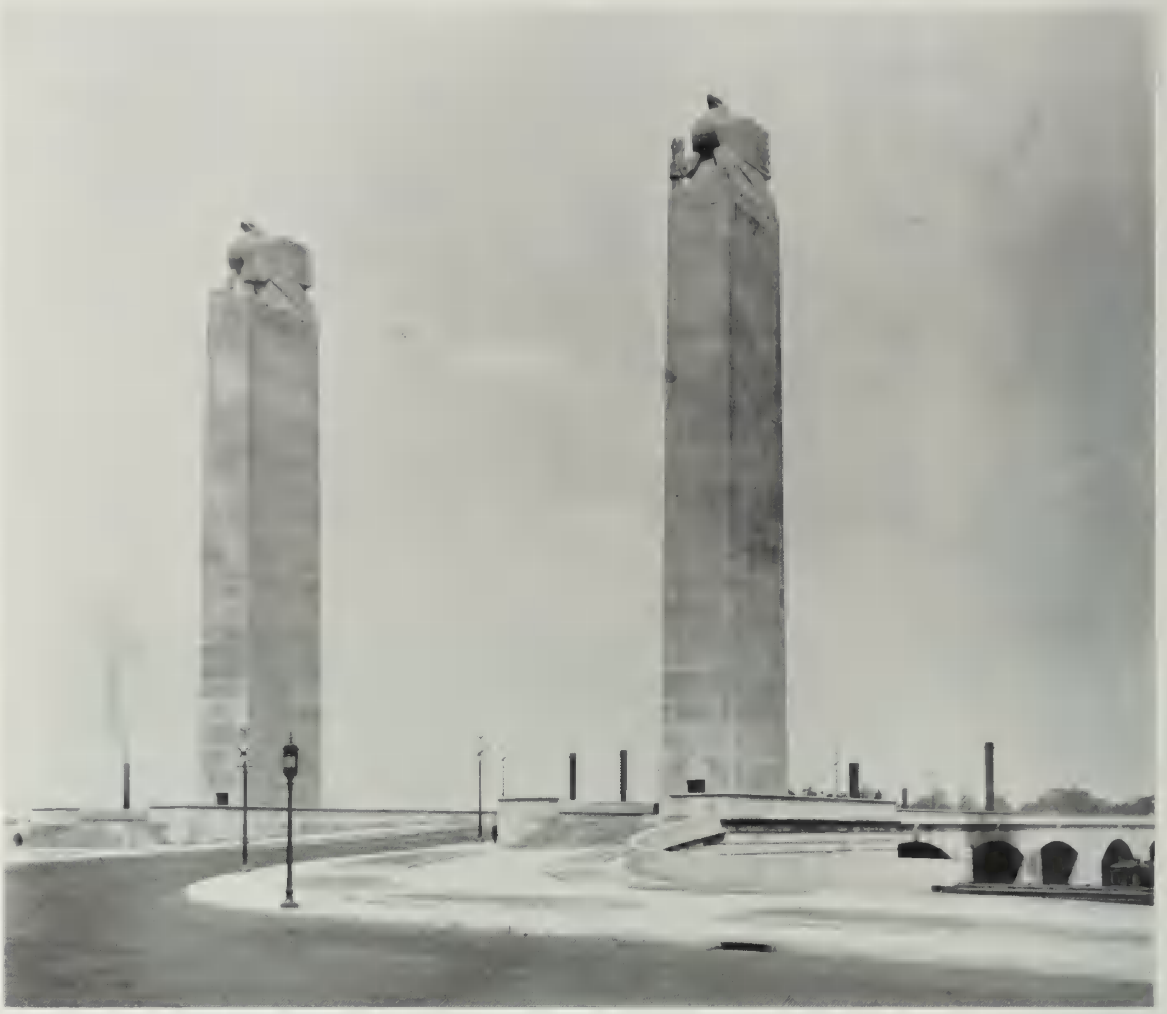
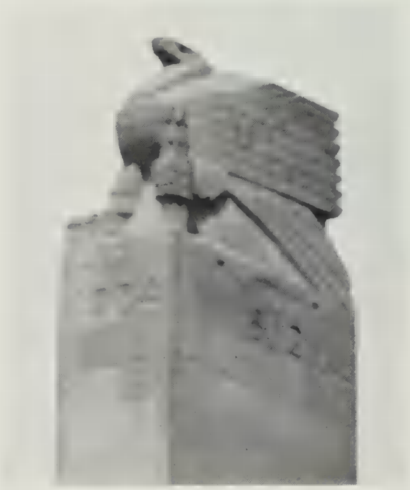


Figure 32. MARKET STREET BRIDGE OVER THE SUSQUEHANNA RIVER, HARRISBURG, PENNSYLVANIA—1927



Photos, Courtesy Indiana Limestone Co.



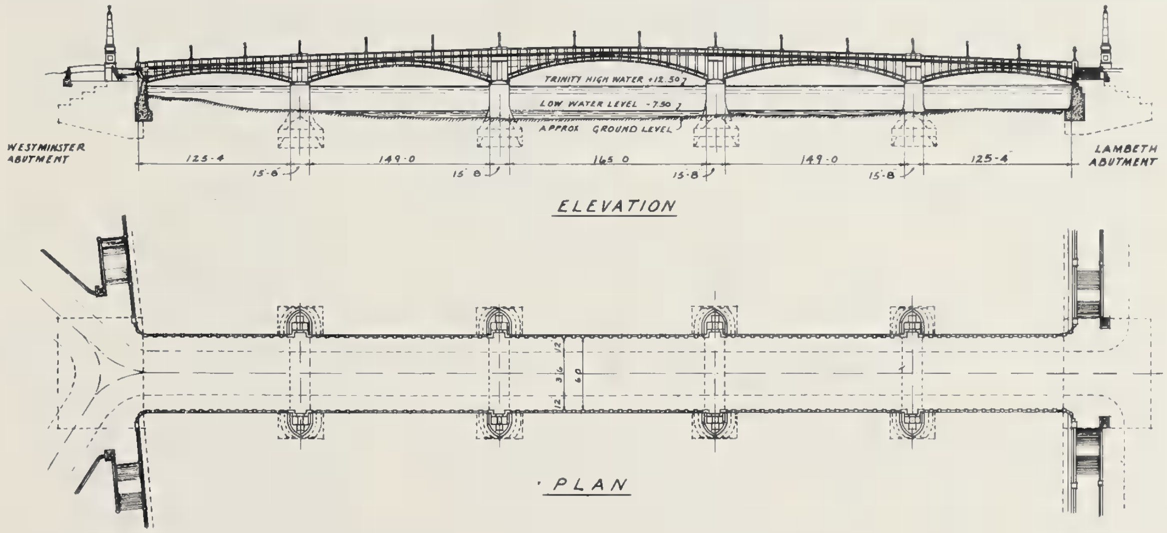
Figures 33, 34. ENTRANCE—SOLDIERS AND SAILORS MEMORIAL BRIDGE, HARRISBURG, PENNSYLVANIA 1930 the Adolph Hitler bridge, if measured between hinges, is 1 to 18.6, which is flatter than the Paris bridge. This bridge has three spans 328, 344½ and 382 7/10 feet in length, all of the three hinged, hollow ribbed, open spandrel type. The ribs are two in number, offset to conform to the skew of the bridge. The deck carries two rapid transit tracks, a 39.4-foot roadway and two 9.8-foot wide sidewalks. The hollow ribs are thickest at the quarter points of the span, 8.4 feet, and the maximum stress on reinforced concrete is 1,280 pounds, which is the limit set by the standardization committee of Germany. The foundations are on rock about 60 feet below high water level, placed by the pneumatic caisson method.

LA ROCHE GUYON, FRANCE, BRIDGE OVER THE SEINE

This is a reinforced concrete part-through arch bridge, and is the longest of this type in the world, having a length of 528 feet with a rise of 75.5 feet. It carries a single roadway 18.4 feet wide. The arch ribs are fixed, and, as is customary in recent European practice, are hollow;—the crown section having a depth of 8.7 feet and a width of 4.6 feet the corresponding dimensions at the spring being 4.7 feet and 9.8 feet. The engineer was S. Boussiron.

LONDON, NEW THAMES RIVER BRIDGE AT LAMBETH

The latest of the old bridges over the Thames at London to be replaced by a modern structure is P. W. Barlow's Suspension Bridge at Lambeth, completed in 1862, and notable because it was the first suspension bridge to make use of stiffening trusses. The construction of the new bridge illustrates what



· PLAN & ELEVATION OF THE LAMBETH BRIDGE ·
LONDON ENGLAND

Figure 35.

has become a more or less standard type for new London bridges over the Thames.

The design of these modern London bridges consists of a series of steel plate girder arches of flat segments and moderate spans supported on massive masonry abutments and piers. The Southwark bridge, replaced about a decade ago, is of this same type and the new Waterloo Bridge, soon to replace the famous old structure now being demolished, will also be similar to that at Lambeth.

The Lambeth bridge has five spans, increasing in length from the shores to the center, the shore spans being 125 feet long, the center 165, and the intermediate 149 feet. The foundations are of steel caissons filled with concrete and sunk to about 25 feet below the river bed by the pneumatic process. It was completed in 1932, after designs by Sir Geo. Humphreys, Chief Engineer, with Sir Reginald Blomfield, R. A., and Mr. G. Topham Forrest as collaborating architects.

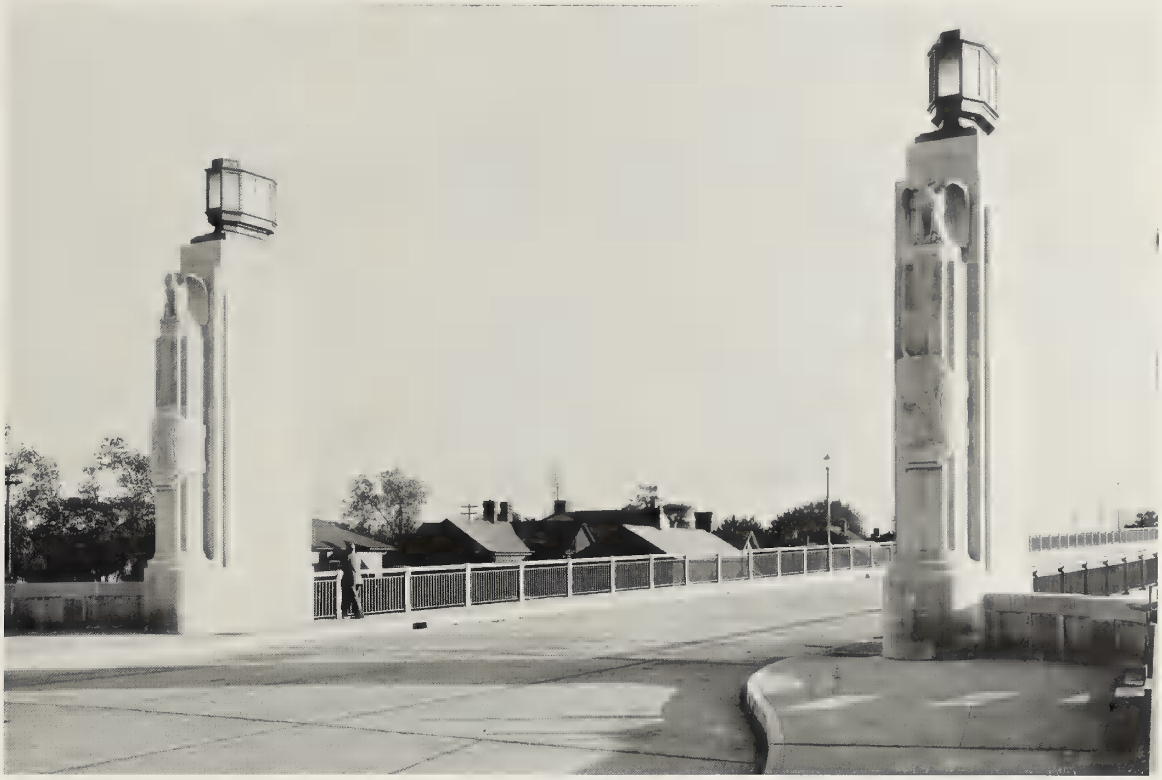
LONGVIEW, WASHINGTON, HIGHWAY TOLL BRIDGE OVER THE COLUMBIA RIVER

A privately owned highway toll bridge over the Columbia River, fifty miles below Portland, Oregon. It is of the cantilever type, 1,200 feet main span and 760 foot arms, providing a clearance over the channel of 195 feet above low water. The foundations of the main piers at a depth of about 72 feet are on timber piles, and underwater concrete was used for the full depth. The Strauss Engineering Corporation of Chicago were the engineers.

LOUISVILLE, KENTUCKY, MUNICIPAL BRIDGE

The Louisville Municipal Bridge, so-called because it was financed and built by the City of Louisville, crosses the Ohio River connecting Louisville with Jeffersonville, Indiana. The length of the main structure over the river is 3,740 feet, the total length 5,750 feet.

The main structure comprises twin cantilevers, each having a main span of 820 feet center to center of piers, and anchor arms of 500 feet and 362 feet. These cantilever spans are splendid examples of good design for this type of structure. The only ornamental treatment consists of the two pylons at each end of the bridge, constructed of Indiana limestone and surmounted by ornate lanterns and craved eagles over the coats of arms of the two states. The river bottom at the site of the bridge is limestone rock at from 16 feet to 66 feet below pool level. All piers were founded upon rock, except at the Kentucky shore, and were sunk by the pneumatic method, except the bank piers where concrete caissons were founded by open dredging. All river piers were built on steel caissons and are of concrete faced with granite. The roadway is 38 feet wide between curbs, sidewalks 5 feet wide, and the clearance above pool stage is 80 feet. The concrete roadway slab is 7 inches thick and no wearing surface is provided. Curbs are 10 inches deep. In erecting the steel work for the cantilever spans, four derricks were used working out from each pier,—two erecting the anchor arms while the other two simultaneously placed the cantilever arms and suspended spans, maintaining proper balance on the piers.



Photos, Courtesy Indiana Limestone Co.

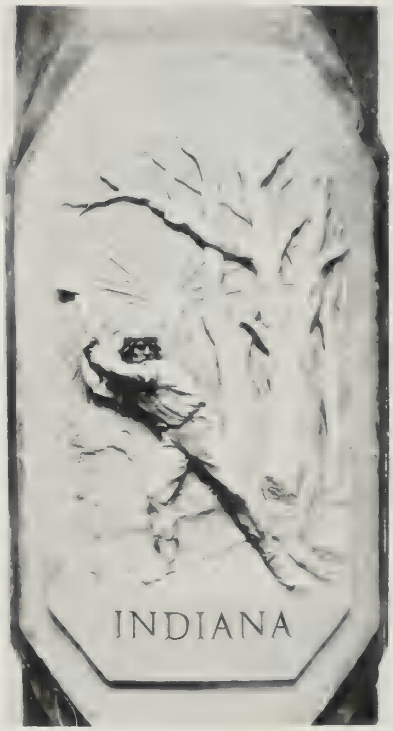
Figure 36. LOUISVILLE MUNICIPAL BRIDGE OVER OHIO RIVER, LOUISVILLE, KENTUCKY

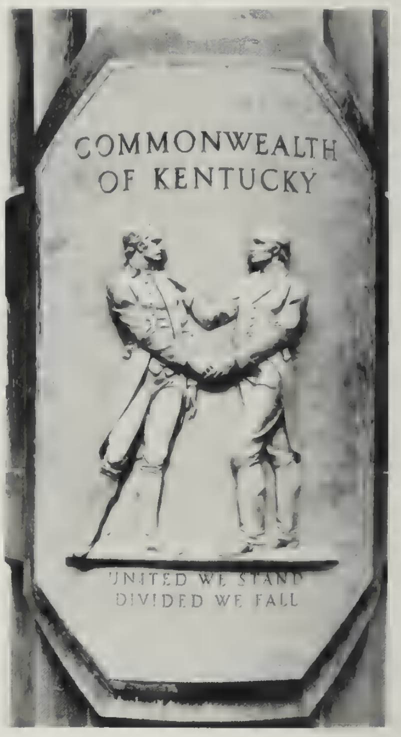
Modjeski & Masters, Engineers. 1930 *Paul P. Crét, Architect.*

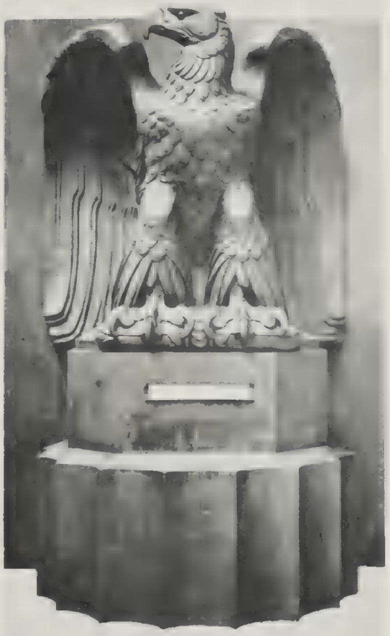
Approximately 33,000 cubic yards of masonry were used and 14,000 tons of structural steel, involving the expenditure of about $3,540,000 for construction or $4,771,000 total cost inclusive of land, administration and financing. It was financed by the sale of revenue bonds; that is, the sole security for such bonds were the revenues to be collected by tolls, a system, by the way, that is not new, for a bridge over the Thames at Kingston, in England, was financed in this way over 100 years ago.

LOUISVILLE, KENTUCKY
KENTUCKY AND INDIANA TERMINAL RAILROAD BRIDGE OVER BROADWAY

This is an interesting example of a rigid frame railroad bridge over a city street executed in steel. The designer has made no attempt to disguise any







Figures 37, 38A, 38B. ENTRANCE PYLONS AND SCULPTURAL DETAILS
LOUISVILLE MUNICIPAL BRIDGE OVER OHIO RIVER, LOUISVILLE, KENTUCKY

necessary structural feature, nor has he added any ornamentation. The design is purely functional, and in view of the recent tendency toward the application of the principles of the rigid frame to structures of this kind, it is interesting as illustrating the possibilities of the type. Fellheimer and Wagner, architects and engineers of New York, designed this structure in 1930.

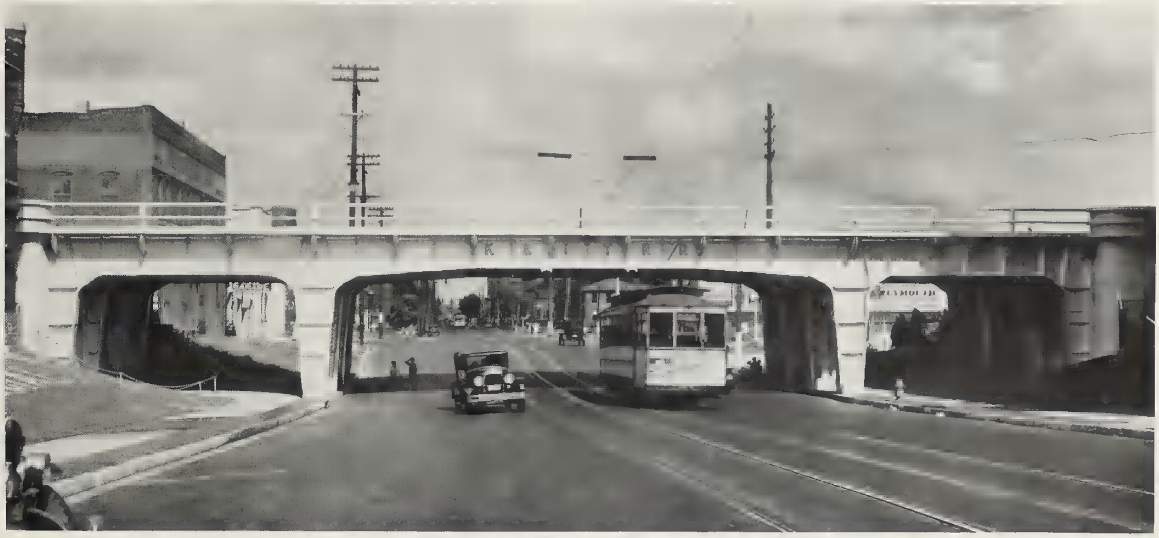


Figure 39. KENTUCKY & INDIANA TERMINAL RAILROAD BRIDGE OVER BROADWAY, LOUISVILLE, KENTUCKY

MAYSVILLE, KENTUCKY, HIGHWAY BRIDGE OVER THE OHIO RIVER

Opened November 25, 1932. This bridge is a publicly owned toll bridge built by the State of Kentucky and is of the parallel-strand cable suspension type with a main span of 1,060 feet and side or anchor spans of 465 feet each. The 13-inch cables contain 61 prestressed strands. The roadway width is 20 feet wide and the one sidewalk is 4 feet 8 inches wide. Modjeski, Masters and Chase were the engineers.

MINNEAPOLIS, MINNESOTA, FORD BRIDGE OVER THE MISSISSIPPI RIVER

Completed in 1927, this reinforced concrete arch bridge has a total length of 1,522 feet and consists of three spans 300 feet long over the river flanked by a shorter arch span and a girder span at each end, an example of perfect symmetry in design.

MINNEAPOLIS, MINNESOTA, FORT SNELLING-MENDOTA BRIDGE OVER THE MISSISSIPPI RIVER

A reinforced concrete structure built in 1926. Contains 12 arches of the open spandrel two ribbed type. 283 foot spans. Engineers—W. H. Wheeler and the C. A. P. Turner Company.

MONTREAL, CANADA, HARBOR BRIDGE OVER THE ST. LAWRENCE RIVER

A cantilever type of 1,097-foot main span and 420-foot side spans, center to center piers; 8,817 feet long over all steel structure. Monsarrat and Pratley were the construction engineers, with J. B. Strauss as associate.

The design is of the same general type as the Quebec bridge, comprising a suspended span of 378 feet and involving long approaches of steel trusses. Approximately 33,200 tons of steel were used in the construction of this bridge, of which nearly 14,000 were silicon alloy. The trusses are spaced 66 feet 6 inches apart, and carry a center roadway 36 feet 10¾ inches wide and two railway tracks, one on each side of the roadway. Two 5-foot walks are provided outside of the main trusses. The arrangement of the truss members, utilizing a K system, is unusual, and the magnitude of the structure entitles it to a place among the world's greatest cantilever structures.

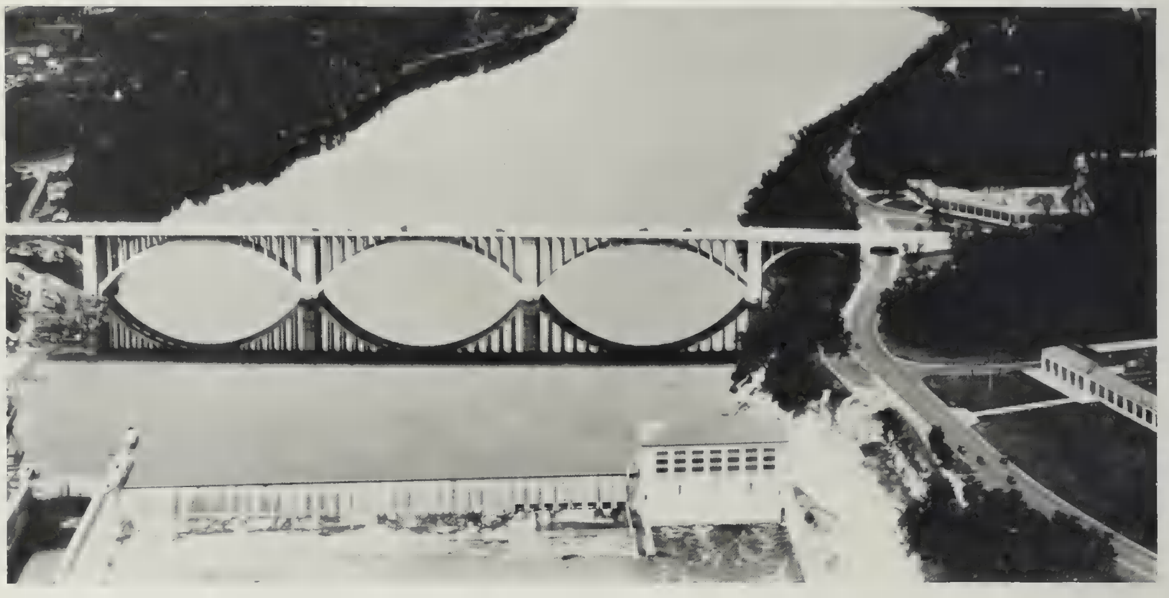


Figure 40. THE FORD BRIDGE OVER THE MISSISSIPPI RIVER, MINNEAPOLIS, MINNESOTA
M. S. Grybak, Designing Engineer

MORGAN CITY, LOUISIANA, ATCHAFALAYA BRIDGE

At Morgan City, the State of Louisiana has constructed a highway bridge that embodies two notable features;—deep and difficult foundations, and long steel trusses in which the K system of web members were used.

The bridge is on the Old Spanish trail (U. S. route 90) and was completed in 1933. It consists of three through truss spans 608 feet in length. The water where the piers are located is 53 feet deep, and the river bottom is composed of semi-fluid mud 30 to 40 feet deep;—suitable soil for foundations being found

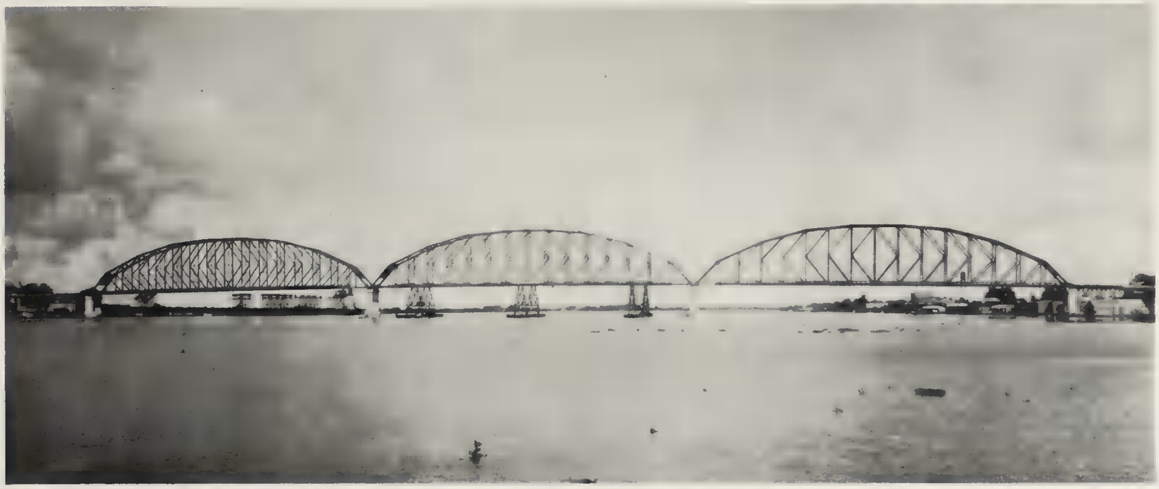


Figure 41. HIGHWAY BRIDGE OVER THE ATCHAFAYALA RIVER, MORGAN CITY, LOUISIANA
N. E. Lant, Bridge Engineer, Louisiana Highway Commission—1933

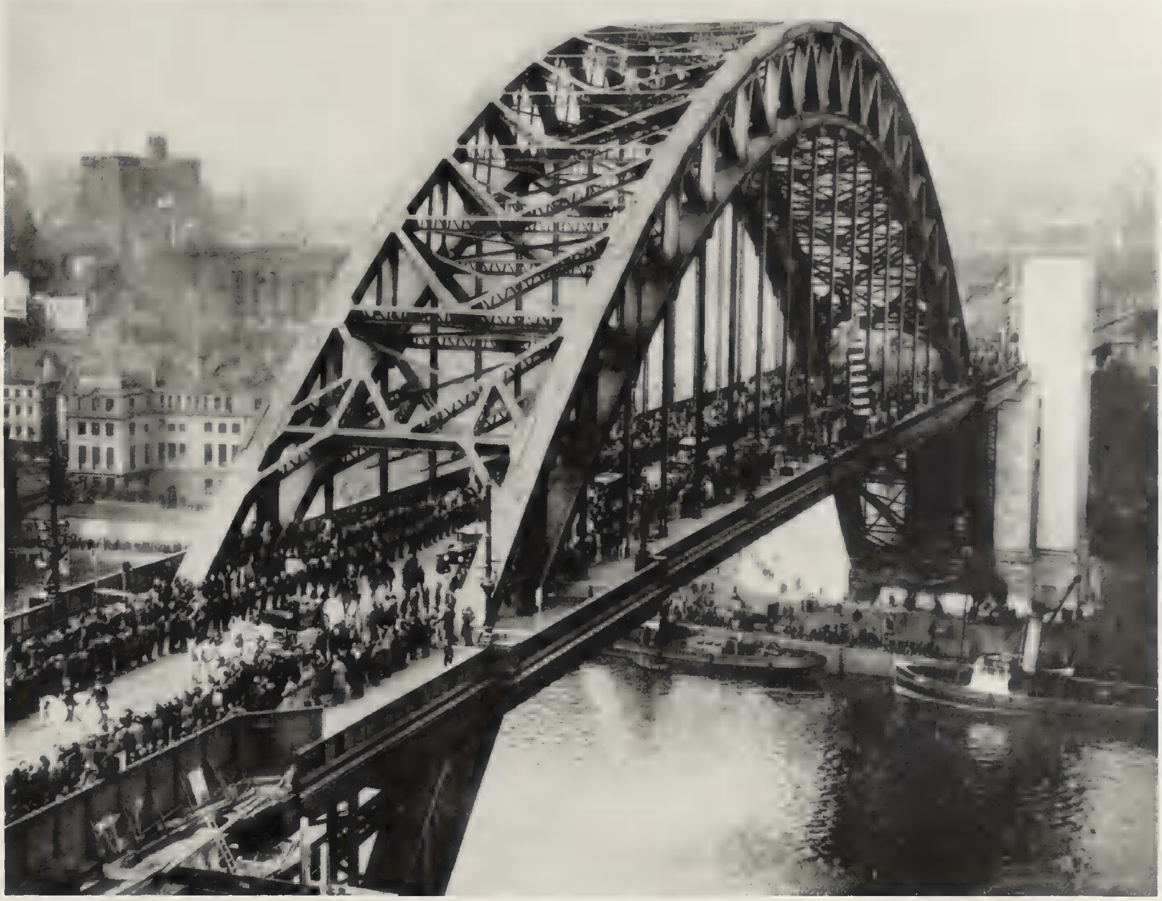


Figure 42. THE NEW TYNE BRIDGE, NEW CASTLE, ENGLAND—1928

at a depth of 176½ feet below water. Steel caissons 44 feet in diameter were used, floated to position and dredged out through an open well 20 feet in diameter until a depth of 85 feet was reached when air was applied and the balance dredged out by pneumatic methods using as high as 49.5 lbs. per sq. inch air pressure. The steel deck of the working chamber was removed by divers after the caisson was bedded and a 24-foot concrete seal deposited under water. It is worthy of note that the cutting edge sections of these caissons, 30 feet in height, were fabricated on the upper Ohio river and transported by water all the way to the site. The trusses are 100 feet deep at center and 28 feet apart, and were erected on barges and floated into position.

NEWCASTLE, ENGLAND, THE NEW TYNE BRIDGE

This bridge is the latest descendent of a long line of ancestors to cross the Tyne at Newcastle. The first for which records exist, was built by the Roman Emperor Publius Aelius Hadrianus about the year 120, and was called the Pons Aelii after him. Like most Roman bridges, it consisted of timber beams supported on stone piers and served thus for over a thousand years. It was replaced by a stone bridge about 1250, a typical medieval structure which carried houses, shops and a prison flanking its 15-foot roadway. This bridge served for about five hundred years when it was destroyed by a flood.

The third bridge, also of stone, was completed in 1781, and demolished and replaced in 1876 by a swing bridge which served until the completion of the present structure,—completing an unusual historical bridge record.

The new bridge is a handsome steel arch of 531 feet span, providing 88 feet, 3 inches headroom for vessels, a roadway of 38 feet and two 9-foot walks. The foundations for the abutment piers were carried to rock at 60 and 40 feet by concrete caissons sunk by the pneumatic process. The arch is two-hinged.

The designing engineers were Messrs. Mott, Hay and Anderson, assisted by R. Burns Dick, architect. The photograph depicts the opening of the bridge with elaborate ceremony on Oct. 10th, 1918. Their Majesties, the King and Queen, are in the carriage in the foreground.

NEW ORLEANS, LOUISIANA, RAILWAY AND HIGHWAY BRIDGE OVER THE MISSISSIPPI RIVER

This bridge, named the Huey P. Long Bridge in honor of the late Senator of that name, is located about ten miles above the 'old city' of New Orleans, and consists of a main structure 3,524 feet, 10 inches long of the cantilever type, comprising a main channel span of 790 feet center to center of piers, with side spans of 529 and 531 feet length. The clearance over average high water is 135 feet. The structure was started in 1933 by the Public Belt Railroad Commission and the State of Louisiana, and completed in 1936 at a cost of about

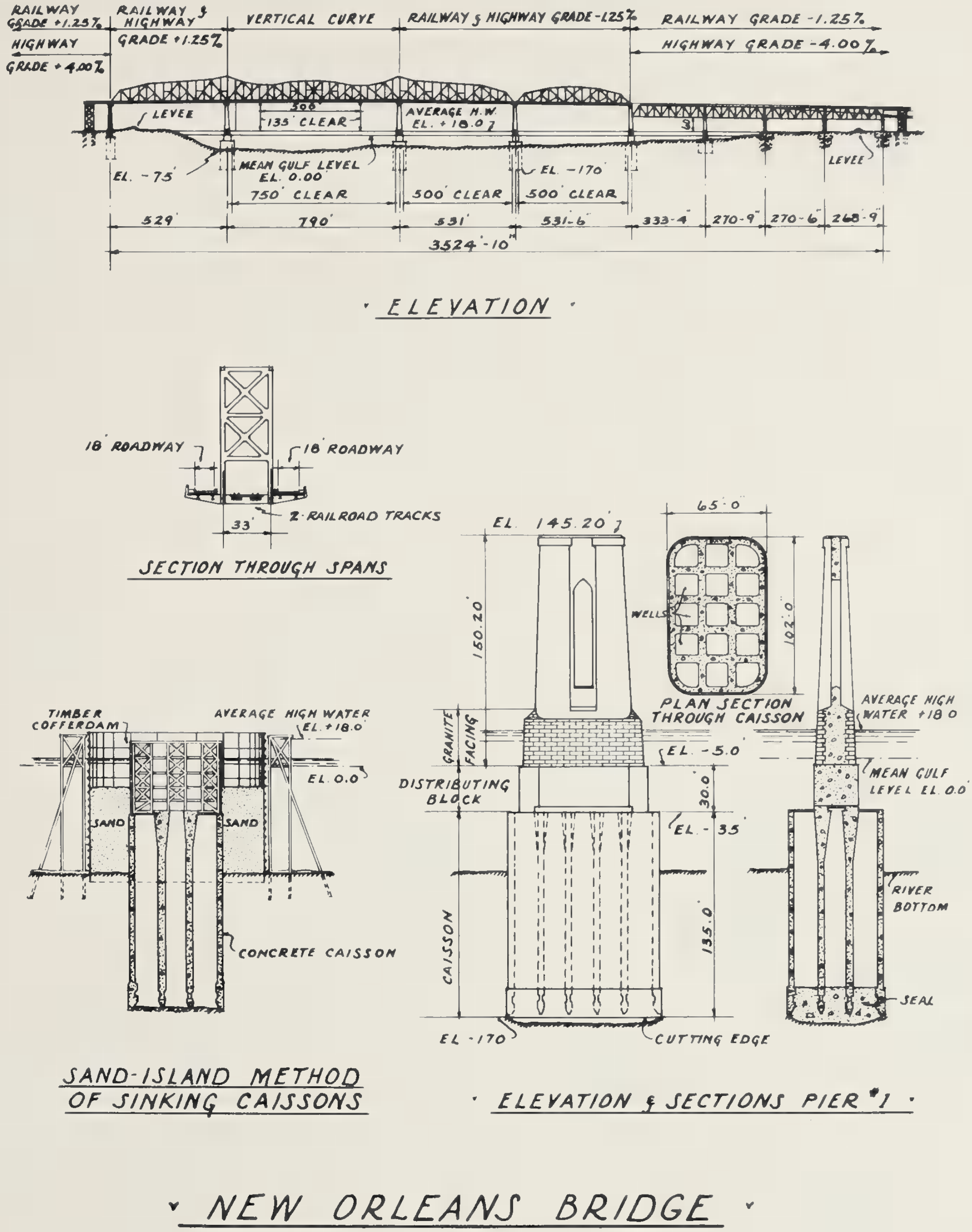

RAILWAY GRADE +1.25%
HIGHWAY GRADE +4.00%
RAILWAY & HIGHWAY GRADE +1.25%
VERTICAL CURVE
RAILWAY & HIGHWAY GRADE -1.25%
RAILWAY GRADE -1.25%
HIGHWAY GRADE -4.00%
LEVEE
300
135' CLEAR
AVERAGE H.W. EL. +18.0
EL. -75'
MEAN GULF LEVEL EL. 0.00
EL. -170'
LEVEE
750' CLEAR
500' CLEAR
500' CLEAR
529'
790'
531'
531-6"
333-4"
270-9"
270-6"
268-9"
3524'-10"
ELEVATION
18' ROADWAY
18' ROADWAY
2 RAILROAD TRACKS
33'
SECTION THROUGH SPANS
TIMBER COFFERDAM
AVERAGE HIGH WATER EL. +18.0'
EL. 0.0
SAND
SAND
CONCRETE CAISSON
SAND-ISLAND METHOD OF SINKING CAISSONS
EL. 145.20'
150.20'
GRANITE FACING
DISTRIBUTING BLOCK
CAISSON
EL. -170
CUTTING EDGE
65'-0"
WELLS
102'-0"
PLAN SECTION THROUGH CAISSON
EL. -5.0
30.0
EL. -35
135.0
AVERAGE HIGH WATER +18.0
MEAN GULF LEVEL EL. 0.0
RIVER BOTTOM
SEAL
ELEVATION & SECTIONS PIER #1
NEW ORLEANS BRIDGE

Figure 43.

$13,000,000. The total length of the bridge and of approaches is 23,000 feet. The approach grades are 1¼% for the two railroad tracks and 4% for the two roadways, each 18 feet wide.

The principal engineering feature of this bridge is the method of founding the piers through unstable material, which was done by open dredging to the unusual depth of 180 feet below gulf level. This dredging is through semi-fluid silt and alternate layers of sand, clay and gumbo, finally landing on compacted sand, with a soil pressure of about 7 tons per square foot. The caissons, of reinforced concrete, are 65 feet wide by 102 feet long and are provided with vertical tubes near the rim for assistance in guiding the settlement by means of the water jet. These caissons were sunk through artificial islands of sand enclosed in circular steel plate shells having a maximum diameter of 121 feet resting on a willow mattress 250 feet wide by 500 feet long sunk with rip-rap to the river bed.

When the shells reached the mattress, it was cut through by divers working inside the inclosure; the shells were filled with sand; and on the island thus formed caisson sinking was carried forward by open dredging. Similar methods were used by this same contractor for a bridge across Suisun Bay in California. A concrete seal about 25 feet thick was deposited by a tremie requiring a total length of pipe of 191 feet. The cofferdams were then unwatered and the balance of the pier built in the dry. A feature of the foundation work was the careful physical analysis of the subsoil samples obtained by borings, including consolidation tests to determine the probable resettlement. No allowance was made for skin friction in proportioning the piers. The principal advantages of the Sand Island method of preparing foundations are greater safety from damage by floods; greater accuracy of sinking caissons, insuring less danger from tipping, a common occurrence; and the provision of a fixed working area.

Mr. Engel in "Civil Engineering" for December 1935 calls attention to the prevalence of the cantilever type of truss for all bridges over the Mississippi below Thebes, Illinois, due to the absence of rock foundations.

Personnel:

The designing and supervising engineers were Modjeski, Masters and Chase, with Moran and Proctor as consultants on foundations.

NEWPORT NEWS, VIRGINIA, BRIDGE OVER JAMES RIVER

One of the world's longest bridges, 5.58 miles long, comprising 23,178 feet over James River, 2,529 feet over Chuckatuck Creek and 3,761 feet over Nansemond River. It contains 583 identical spans 44 feet long, composed of a concrete deck on steel I beams carried on precast concrete piles, some of which are 115 feet long. The James River crossing contains 17 girder spans of the through type 90 feet long and a 300 foot vertical lift span; the two other crossings contain double leaf bascule spans. Engineers—The J. E. Greiner Company, Baltimore.

NEW YORK, NEW YORK, HENDRIK HUDSON BRIDGE

A spectacular bridge over the Harlem River at the Spuyten Duyvel, the northern end of Manhattan Island, was opened for traffic on December 12th, 1936. Named the Hendrik Hudson Bridge, it forms part of the new Henry Hudson Parkway connecting Riverside Drive with the Bronx and Westchester County. The bridge comprises a main span of 800 feet with a rise of 120 feet, the longest fixed arch and the longest plate girder arch in existence. The two arch ribs are 12½ feet deep and 5½ feet wide, of the box type, of silicon steel and are spaced 50 feet apart. The roadway is 42 feet wide and the single sidewalk 4 feet wide. The roadway is an 8 inch concrete slab. As this arch is of the fixed type, it was necessary to effect the closure by the use of hydraulic jacks, in order to introduce the proper stresses in the arch ribs, a proceeding described in detail in the December 1936 issue of "Construction Methods and Equipment."

The principal engineering problems were concerned with the methods of erection, as the foundations are on rock at or near the surface. The erection by means of temporary posts and toggles was quite unique. The total length of the bridge is about 1,530 feet over all steel and the cost was approximately one and one-quarter million dollars. Architecturally, this bridge is notable for

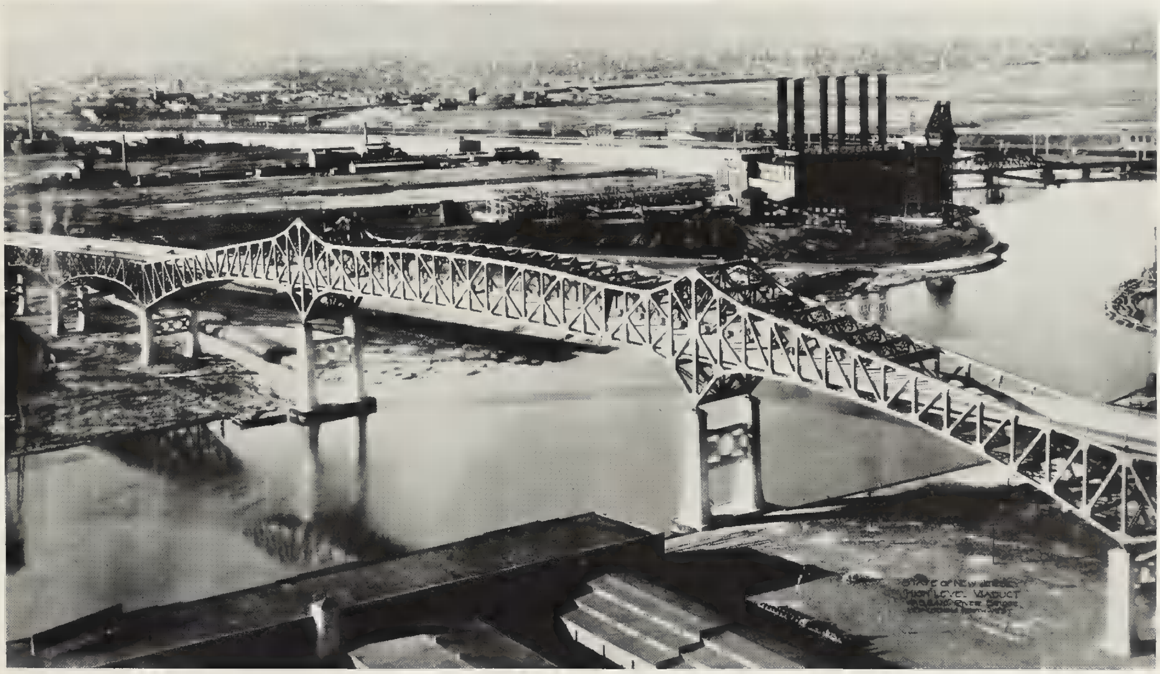


Figure 44. PULASKI HIGHWAY BRIDGE OVER THE PASSAIC RIVER, NEWARK, NEW JERSEY

the simplicity of its design, composed of a single plate girder arch carrying plate steel columns, and steel towers over the abutments. The roadway is carried on plate girders of uniform depth.

The engineers in charge of construction for the Henry Hudson Parkway Authority were Madigan-Hyland, Robinson & Steinman were consulting engineers on the bridge, and Aymar Embury II was consulting architect.

NEW JERSEY, PULASKI HIGHWAY BRIDGE OVER THE PASSAIC RIVER

The elevated highway carrying vehicular traffic to and from the west end of the Holland Tunnel at New York and extending across the Newark Meadows, involved one of the greatest bridge projects of recent years. Completed in 1932, it was awarded first prize by the American Institute of Steel Construction as the most beautiful bridge costing over one million dollars and completed in that year. This improvement is part of the Lincoln Highway and is about twelve miles in length, in the course of which it crosses three navigable rivers;—the Passaic, the Hackensack and the Elizabeth. The bridges over the two first mentioned rivers are especially notable, together with the approach viaducts. This part of the structure is composed of a series of steel cantilever spans with intervening suspended spans, supported on concrete piers. The illustration shows one of the river crossings, comprising a main span of 550 feet center to center bearings, with side spans of 350 feet each and cantilever arms of 75 feet each,—all forming a single continuous unit of 1,450 feet. The two river spans mentioned are distinguished by a gradual change from deck type to through type trusses, quite like the Lake Champlain and Cape Cod Canal bridges in general appearance. Maximum grades are 3½%, clearance over the rivers 135 feet, and the roadway is 50 feet in width with 2-foot refuge walks on each side. Lighting standards are 150 feet apart, staggered, carrying 600 candle power lights at a height of 23 feet above the roadway. This elevated highway is designed to provide for an annual traffic capacity of twenty millions, and actually carried about one-half this amount the first year, with a maximum hourly rate of 5,400 autos. Foundations are carried to rock at depths of from 25 to 141 feet by means of concrete caissons sunk by open dredging and by air. No paving of the 8½-inch concrete roadway slab was used. Curbs are 16 inches high.

The work was executed under the direction of Jacob L. Baur, State Highway Engineer; H. W. Hudson, Chief Engineer; and Sigvald Johannesson, designing engineer.

NEW YORK CITY, THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER

The completion of the George Washington Bridge at New York, opened on October 25, 1931, about a year ahead of its schedule time, marked a great

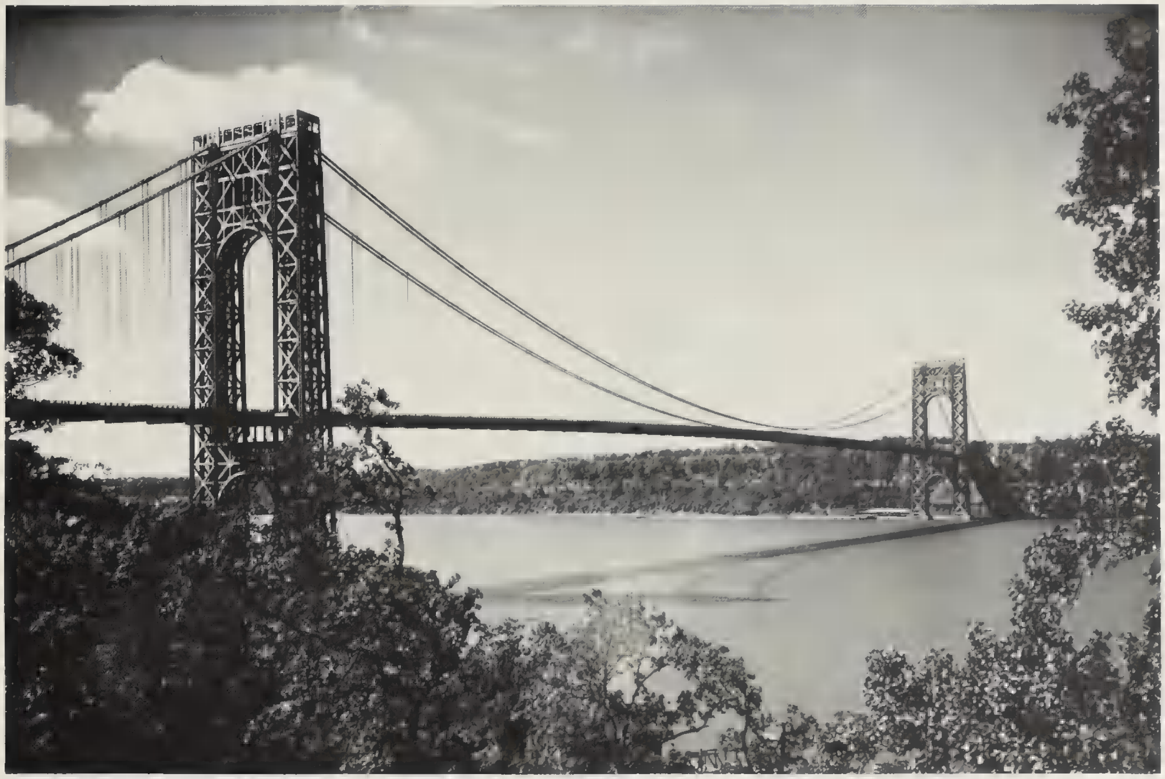


Figure 45. THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER, NEW YORK, NEW YORK

epoch in Bridge Engineering, for it almost doubled at a single stroke the maximum length of span previously attained. The idea of bridging the Hudson at New York with a single span is, however, not new: many eminent engineers had made studies for the project, among them the late Geo. S. Morison, Gustav Lindenthal and Boller, Hodge and Baird. The present project was started in 1925, by legislation of the States of New York and New Jersey, creating the Port of New York Authority with power to proceed with the construction of the bridge and arranging for financing by means of revenue bonds, to be amortized in 25 to 30 years by the collecting of tolls.

General Engineering Data:

The length of span, clearance for vessels, etc. are fixed by navigation requirements, and the natural topography of the site is entirely favorable for a suspension bridge, the ground on both sides being high;— the Palisades on the west side of the river reaching a height of about 280 feet at a distance of only 500 feet from the shore while the general elevation of Washington Heights ridge on the east side, about 1,000 feet from the shore, is approximately 200 feet. The rock lies at a great depth under the center of the river but comparatively near the surface at the shore lines, so that it was possible to found the

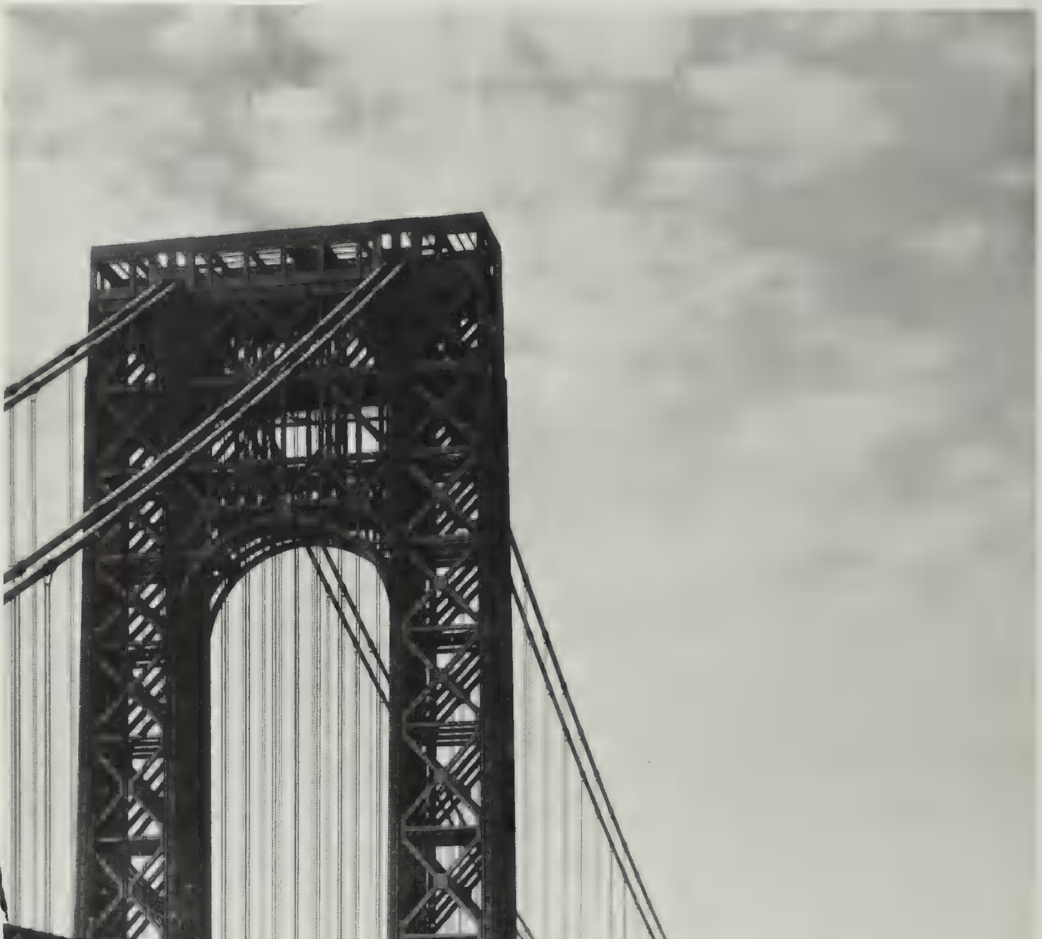


Figure 46. THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER, NEW YORK, NEW YORK

main piers on rock at a maximum depth of 75 feet on the west side and practically at the surface on the east side. The foundations for the west pier were constructed in an open cofferdam, enclosed by steel sheet piling cellular walls. The maximum computed pressure on the rock bottom is 28 tons per sq. foot, and the size of each pier (they are in pairs) is 89 x 98 feet. The Palisades, composed of hard basaltic rock, provided an ideal natural anchorage for the cables on the New Jersey side, all that was necessary was to excavate funnel shaped tunnels in the rock to receive the anchorages, and on the New York side a mass of concrete about 200 feet square with a maximum height above the

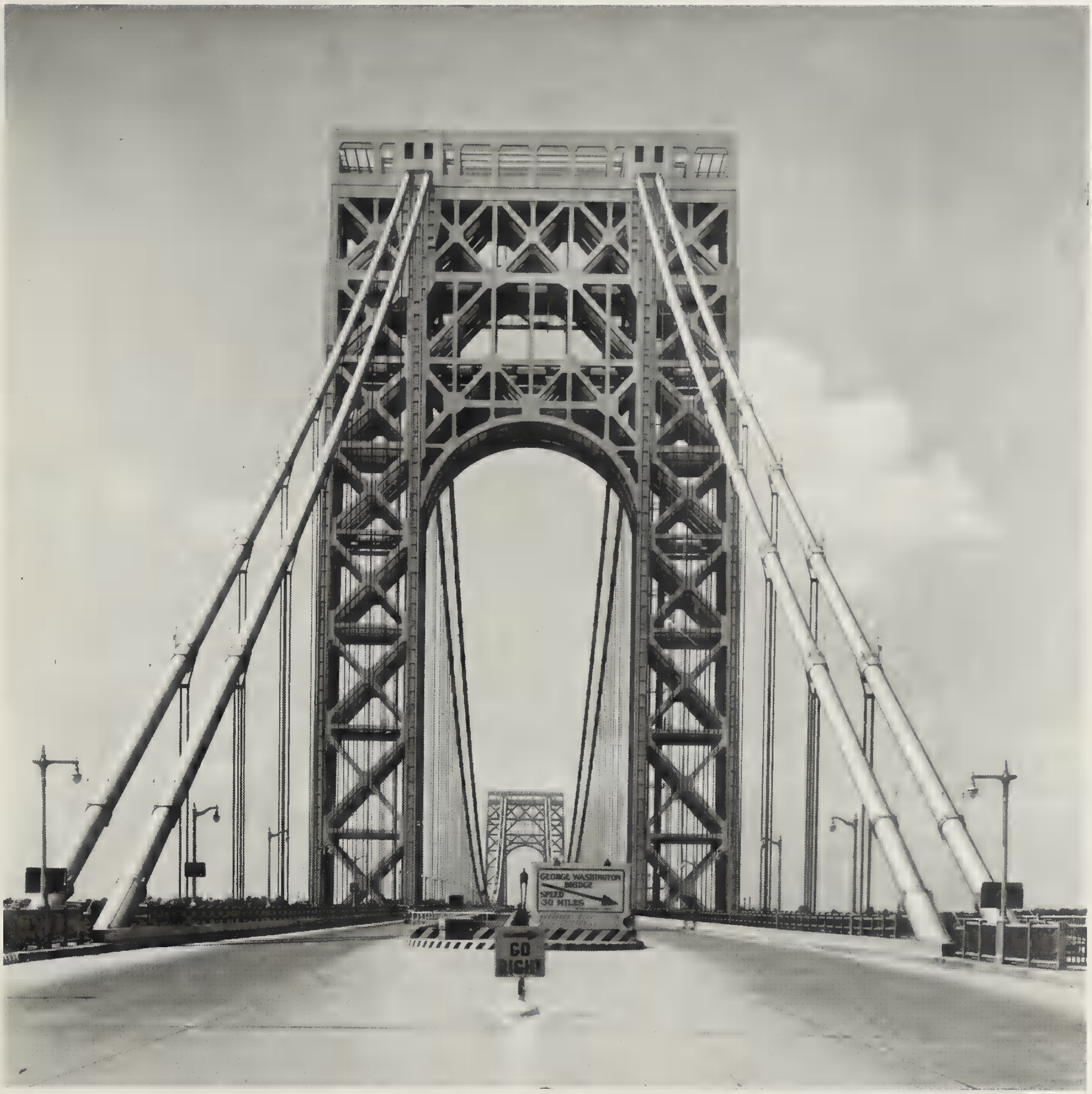


Figure 47. THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER, NEW YORK, NEW YORK

rock of 85 feet sufficed. Better natural conditions for a huge suspension bridge could scarcely be found. The superstructure is extremely simple, consisting of a center span of 3,500 feet between centers of towers, with suspended side spans of 650 feet and 610 feet. It is designed to carry a 90-foot roadway flanked by two 10-foot sidewalks on the upper deck and four electric railway tracks on a future lower deck. The deck as it stands at present provides for two 28-foot, 9-inch roadways and two walks. Four cables are used, with a center sag of 325 feet composed of cold drawn steel wire with an ultimate strength of about 225,000 lbs. per sq. inch. Each cable contains 26,474 galvanized steel wires 0.196 inches diameter, laid parallel. Some idea of the great length of wire required may be had from the fact that the wire used for the cables of this bridge would encircle the earth's equator more than four times. The maximum pull on each cable is about 32,650 tons. A unique feature of this bridge is the fact that as now built, it has no stiffening trusses, these being a part of the lower deck, to be added when that is completed. It is of course the great dead weight of the structure itself as compared to the live load that it carries that makes this possible. The roadway has no pavement, driving being directly upon the reinforced concrete slabs which are seven inches average thickness. Double curbs separate the sidewalk from the roadway, the lower step being 10 inches high and 12 inches wide, the upper step 18 inches high and 7 inches wide, in addition to which a heavy pipe railing between the sidewalk and roadway is provided.

Traffic:

Never before has a great bridge been built, where the problem of traffic approaches has been so carefully and thoroughly worked out, with the intention of facilitating access to the bridge of motor vehicles to the greatest possible extent. This necessitated the building of complete new systems of highways at each end and the elimination of crossings and left hand turns. The old conception of a bridge approach as a simple ramp from the main structure to the ground surface, perhaps terminating in a plaza, does not meet the requirements of modern traffic, but a very careful traffic study of all approach thoroughfares is necessary and frequently a complete rearrangement of streets has to be made. In the case of the George Washington Bridge, these approaches are responsible for about 37% of the total cost of the project. The traffic over this bridge in 1933 amounted to nearly 6,000,000 vehicles. During the first year of its completion about 20,000 pedestrians crossed in a single Sunday, while in 1933 this was reduced to 2,420, demonstrating that most of the pedestrians who came on the bridge during its first year were sightseers. The operating personnel required is about seventy men, and tolls are fifty cents for passenger automobiles. When fully completed, this bridge can carry 25,000,000 vehicles annually, and a peak hour capacity of 1,400 vehicles per hour was used in estimating traffic requirements.

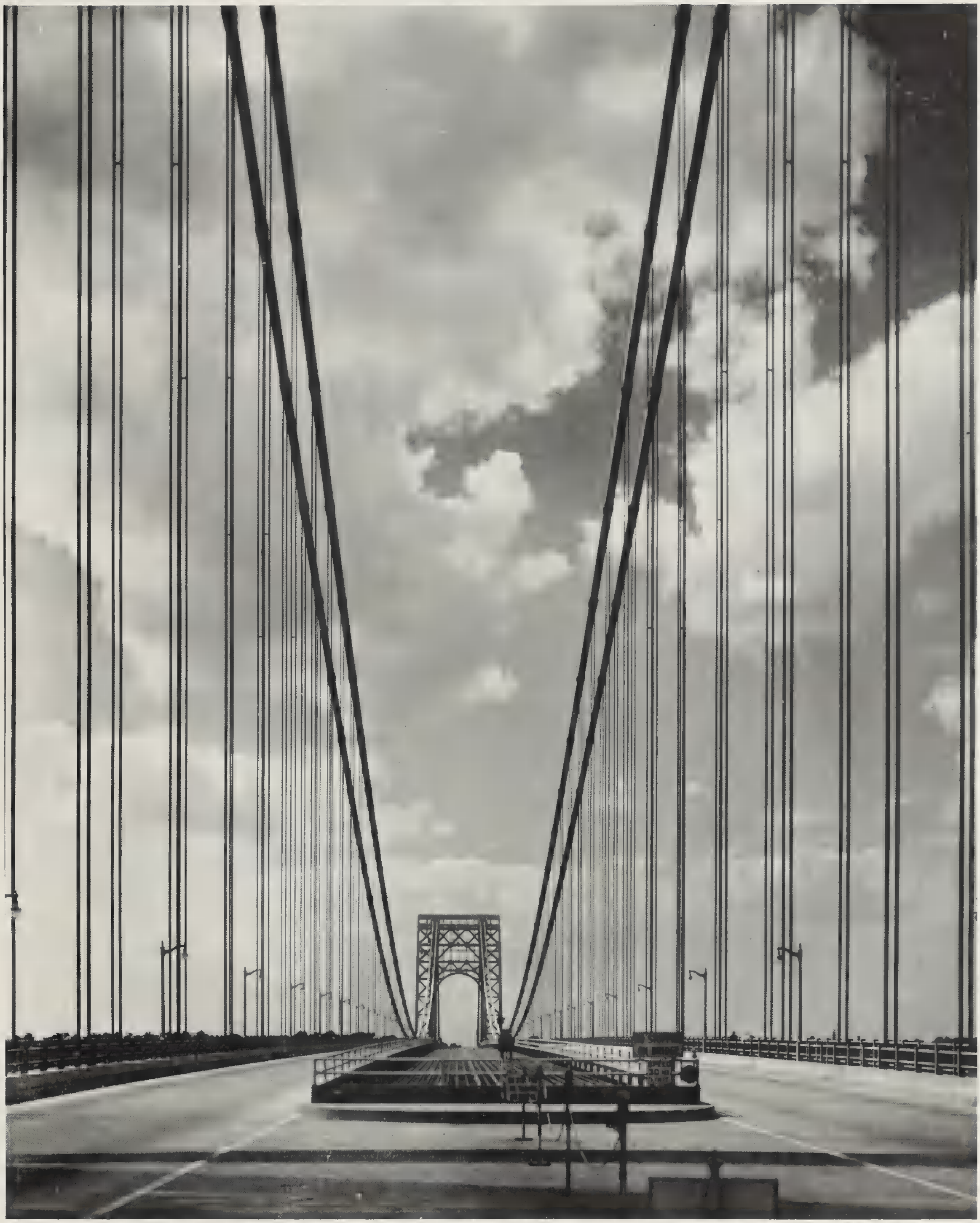


Figure 48. THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER, NEW YORK, NEW YORK

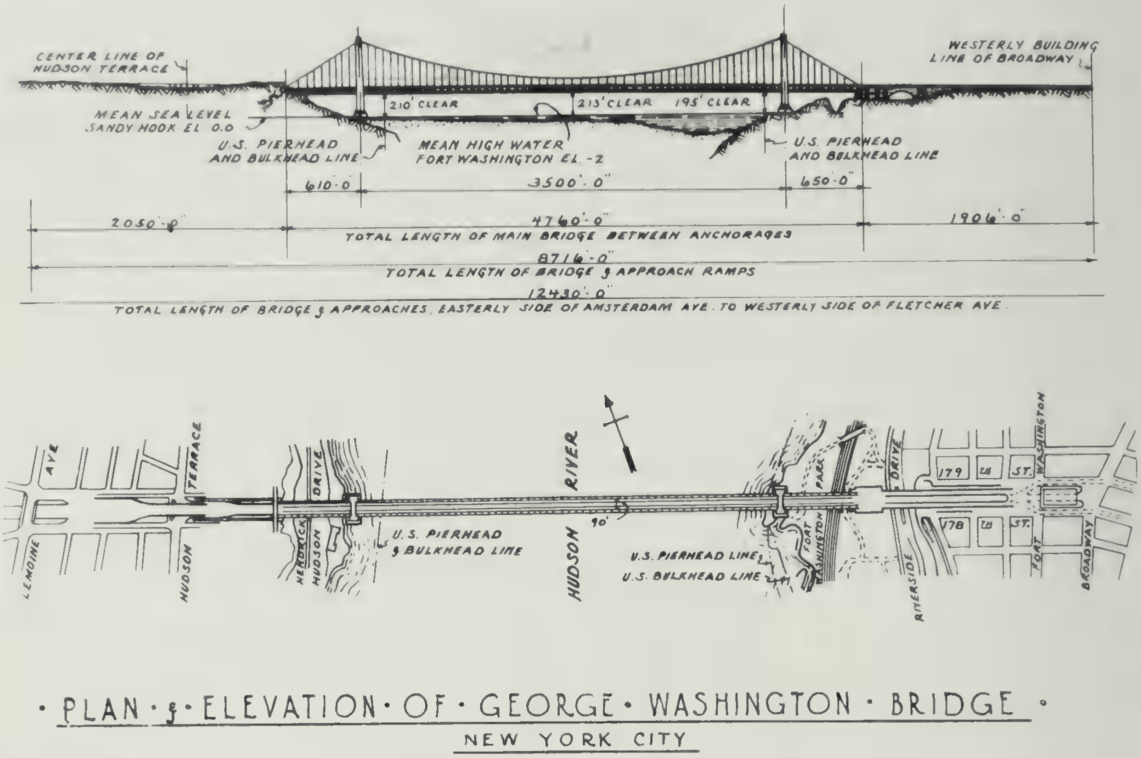

CENTER LINE OF HUDSON TERRACE
WESTERLY BUILDING LINE OF BROADWAY
210' CLEAR
213' CLEAR
195' CLEAR
MEAN SEA LEVEL SANDY HOOK EL 0.0
U.S. PIERHEAD AND BULKHEAD LINE
MEAN HIGH WATER FORT WASHINGTON EL. -2
U.S. PIERHEAD AND BULKHEAD LINE
610'-0"
3500'-0"
650'-0"
2050'-0"
4760'-0"
TOTAL LENGTH OF MAIN BRIDGE BETWEEN ANCHORAGES
1906'-0"
8716'-0"
TOTAL LENGTH OF BRIDGE & APPROACH RAMPS
12430'-0"
TOTAL LENGTH OF BRIDGE & APPROACHES, EASTERLY SIDE OF AMSTERDAM AVE. TO WESTERLY SIDE OF FLETCHER AVE.
LEMOINE AVE
HUDSON TERRACE
HENDRICK HUDSON DRIVE
U.S. PIERHEAD & BULKHEAD LINE
HUDSON RIVER
90°
U.S. PIERHEAD LINE
U.S. BULKHEAD LINE
FORT WASHINGTON PARK
RIVERSIDE DRIVE
179 TH ST.
178 TH ST.
FORT WASHINGTON
BROADWAY
· PLAN · & · ELEVATION · OF · GEORGE · WASHINGTON · BRIDGE ·
NEW YORK CITY

Figure 49.

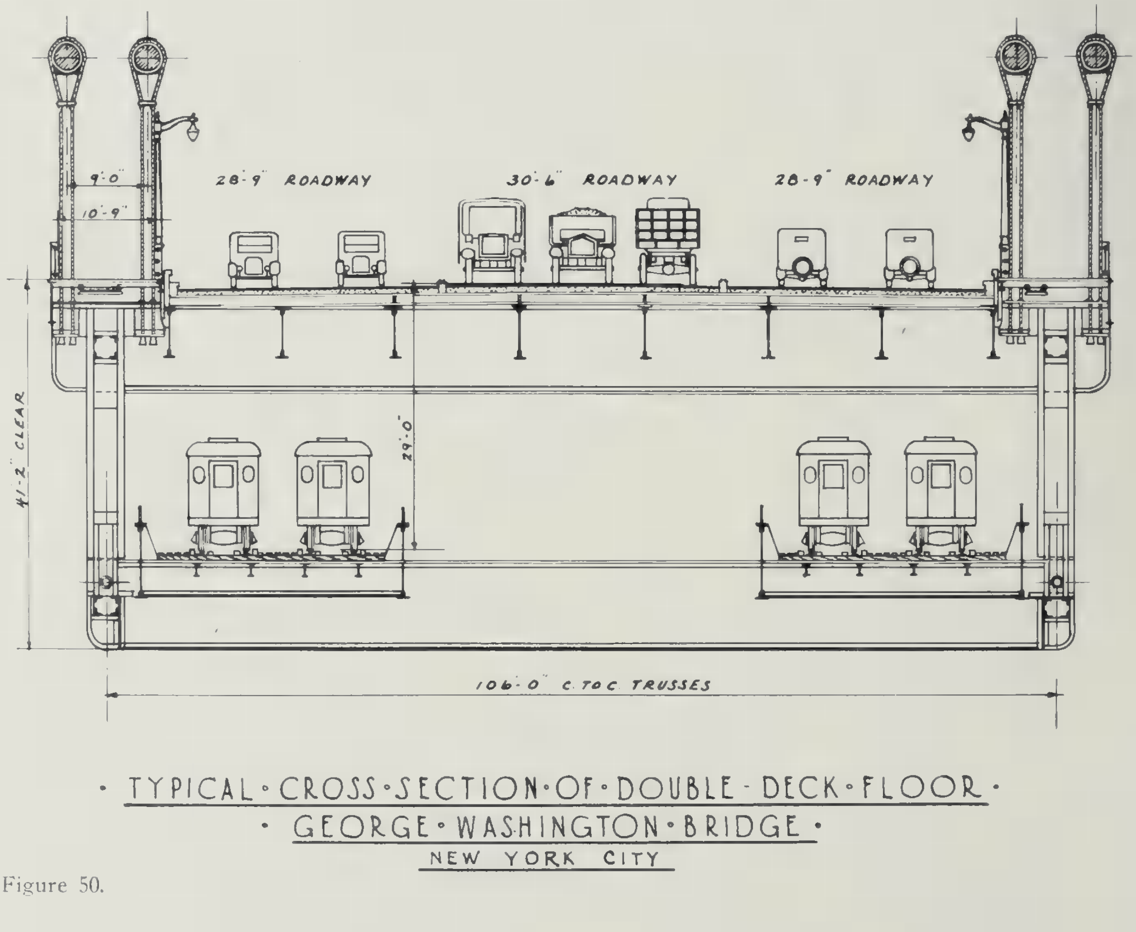


Figure 50.

The appealing beauty of this bridge is due largely, no doubt, to the structural simplicity of the design, comprising only the four great cables, three feet in diameter, from which the floor system is suspended by simple wire ropes. Outside of this the supporting towers excite the most interest. The main cables pass over the tops of these towers at an elevation of 591 feet above high water, and bring upon the tower a vertical load of over 100,000 tons, requiring towers of massive proportions. The original designs intended that these towers be encased in masonry, but this has not been done, and the question of whether or not to so encase has been the subject of considerable discussion. The writer would prefer to leave the structural steel work exposed, but, as Mr. Ammann, the chief engineer, states—"It is futile to theorize about this question—it is largely a matter of aesthetic conception, which is so intensely individual and changeable—nor can it be dealt with on general principles without regard to the local scenery or landscape. Moreover, the aesthetic treatment of a bridge, as that of any other engineering structure, is not always satisfactorily solved even by correct and honest application of engineering principles. The appearance of a structure so conceived may sometimes be materially enhanced by the addition or the architectural embellishment of certain structural parts, whether structurally required or not."

This epochal structure cost about $31,000,000 for the bridge proper, but nearly $24,000,000 more for land, damages and approaches.

Physical Data:

Length of main span	3,500	feet
Length between anchorages	4,760	feet
Total length from Plaza to Plaza	8,200	feet
Width of main structure, overall	120	feet
Height of towers above water	635	feet
Number of cables	4	
Diameter of each cable	36	inches
Number of wires in each cable	26,474	
Diameter of each wire	.0196	inch
Specified strength of wire, minimum	220,000	lbs. per sq. inch
Weight of cable wire	28,450	tons
Height of roadway above water	250	feet
Total structural steel work in main bridge	73,000	tons
Total of steel work in towers	40,200	tons
Masonry in New Jersey tower foundation	37,500	cu. yds.
Rock excavation for New Jersey anchorage and approach	300,000	cu. yds.
Masonry in New York anchorage	165,000	cu. yds.

As is usual in the inception, design, and construction of such a great engineering undertaking, the credit for its success lies with many persons. The organization responsible for this project consisted principally of the following:

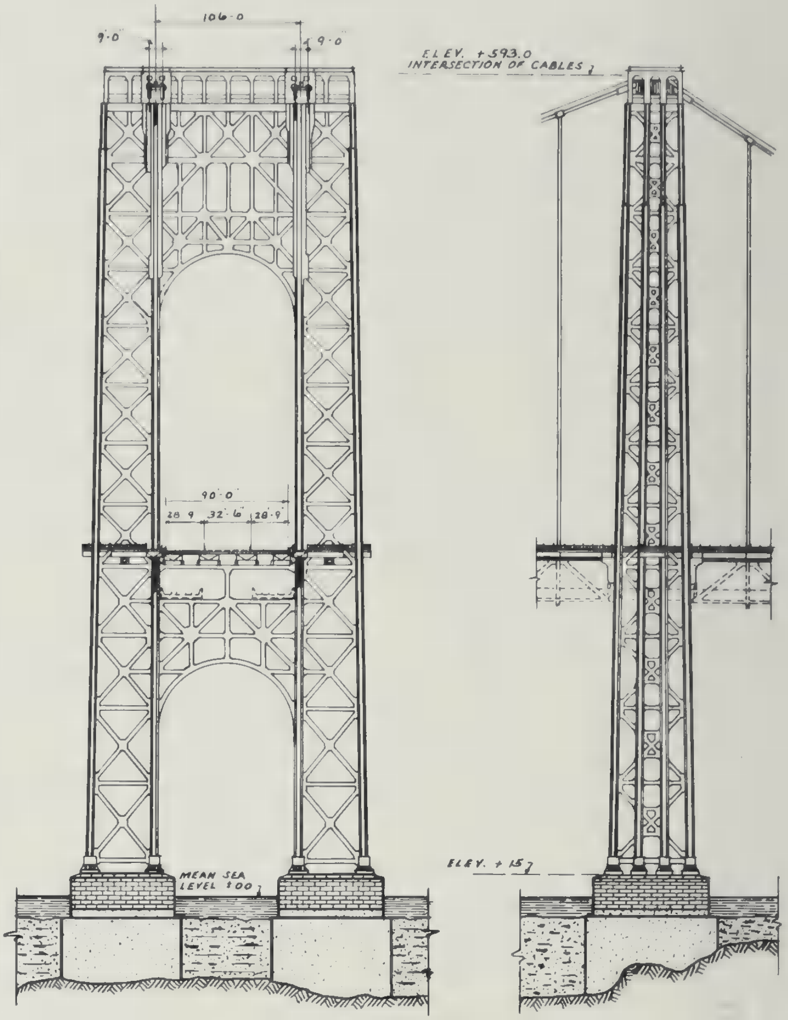
Chief Engineer,
O. H. Amann;

Asst. Chief Engineer,
Edward W. Stearns;

Engineer of Construction, Montgomery B. Case;

Architect,
Cass Gilbert;

Consulting Engineers,
Wm. H. Burr,
Leon S. Moisseiff,
Daniel E. Moran,
Lewis B. Stillwell,
Gustav Lindenthal.



· ELEVATIONS · OF · TOWER ·
· GEORGE · WASHINGTON · BRIDGE ·
NEW YORK CITY

Figure 51.

NEW YORK CITY. RECONSTRUCTION OF THE AQUEDUCT BRIDGE

Originally built in 1842 to carry the Croton Aqueduct across the Harlem River, on a viaduct comprising fifteen handsome masonry arches, it was found necessary recently to remove some of the piers in the river to meet navigation requirements. After a great deal of discussion as to what could be done to preserve as much as possible of the historic old structure, it was finally decided to replace five arches with a single steel span, consisting of a plate girder arch with open spandrels. It would seem that a more harmonious effect could have been produced by designing the new steel span with fewer and larger members.

The reconstruction was designed and executed by the Department of Plant and Structures of New York City.

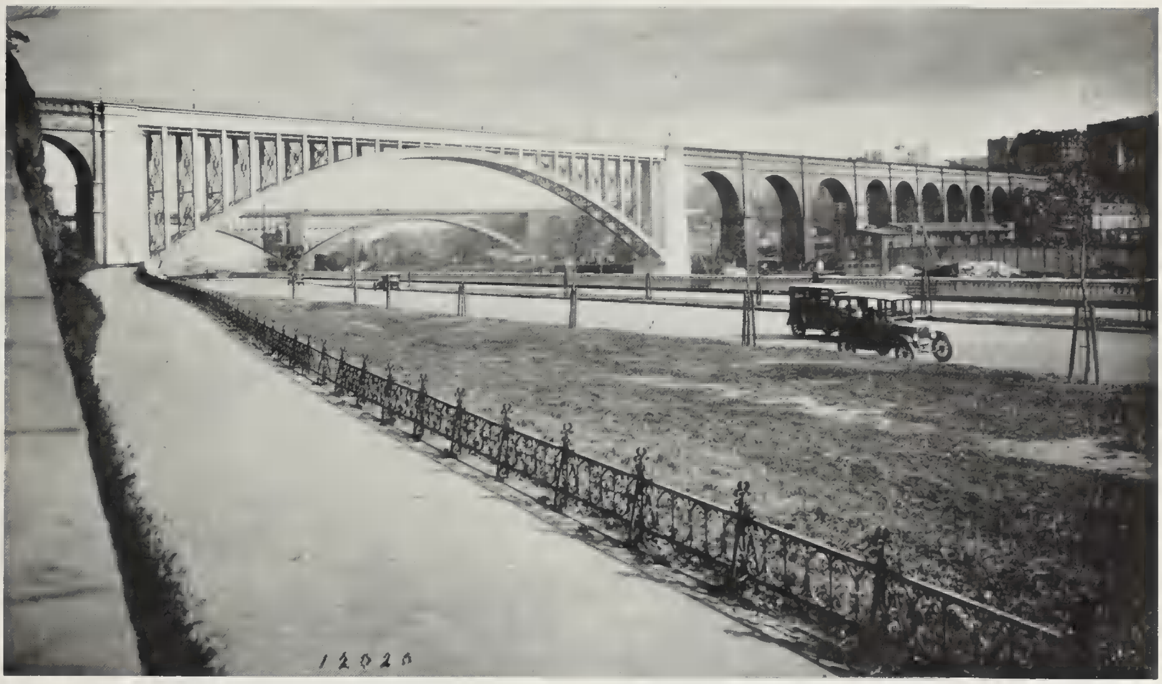


Photo by Theo. E. Blake

Figure 52. THE AQUEDUCT BRIDGE AS RECONSTRUCTED, NEW YORK, NEW YORK

NEW YORK CITY, THE TRIBOROUGH BRIDGE

This bridge, opened with appropriate ceremonies on July 11th, 1936, is, with the exception of the San Francisco-Oakland Bay Bridge, the largest project of its kind undertaken in recent years. It derives its name from the fact that it furnishes communication among three of the boroughs constituting Greater New York City, Manhattan, Queens and Bronx. Crossing the East River just south of the famous Hell Gate Arch, with a suspension span of 1,380 feet, it traverses Wards Island, crosses Little Hell Gate with fixed spans to Randalls

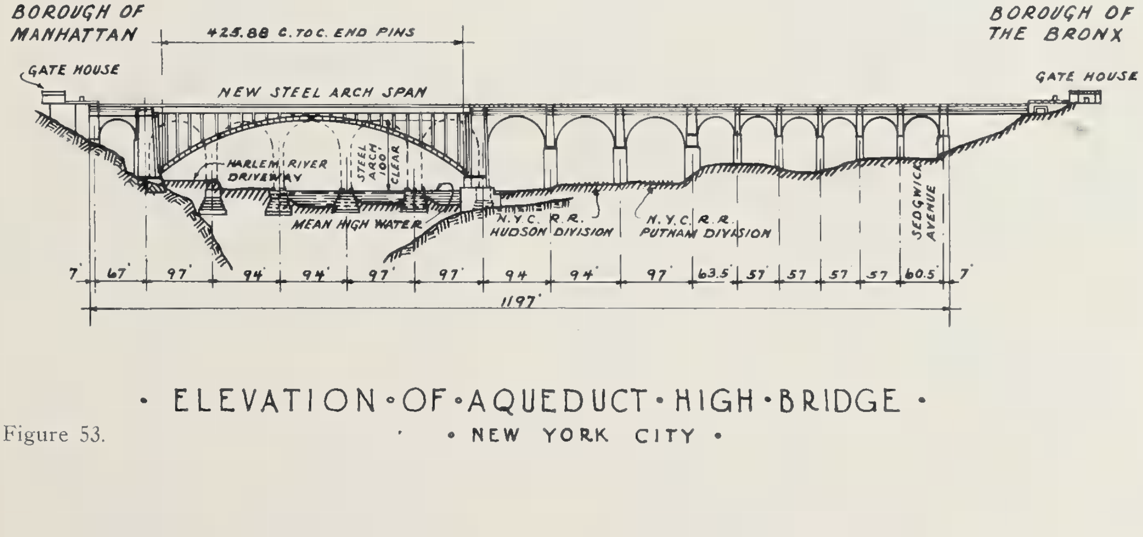
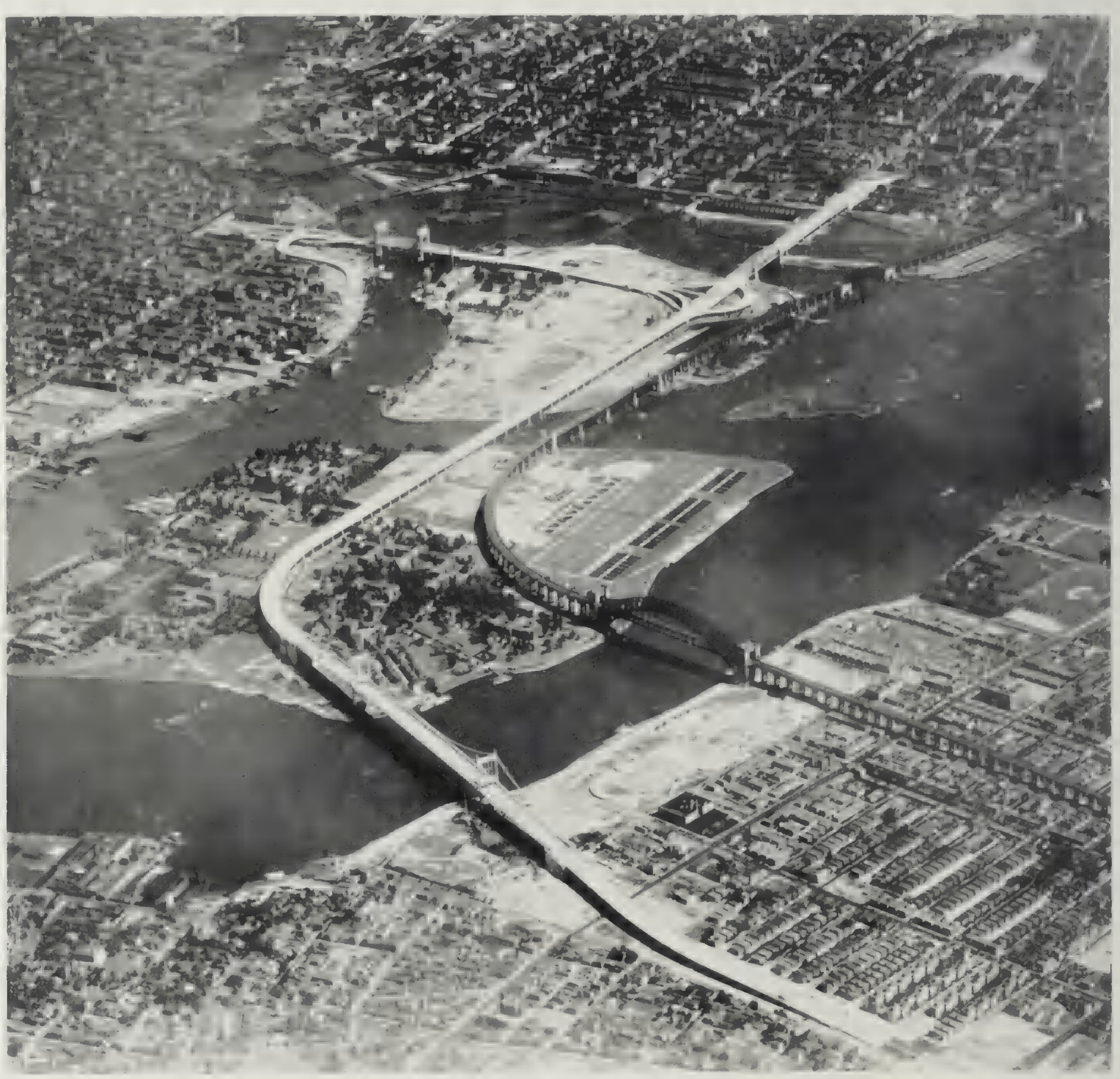


Figure 53.



Photo, Courtesy McLaughlin Aerial Surveys From Wide World

Figure 54. THE TRIBOROUGH BRIDGE, NEW YORK, NEW YORK

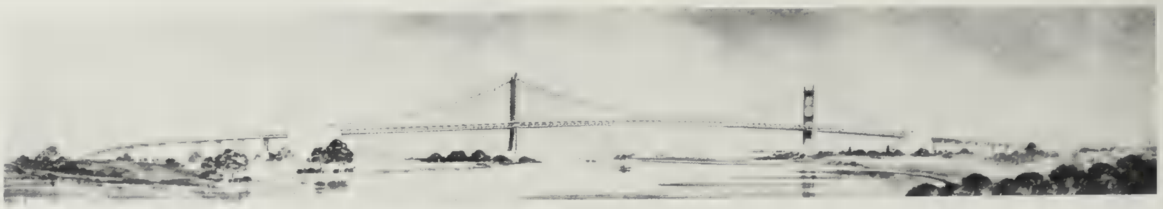


Figure 55. THE TRIBOROUGH BRIDGE—SUSPENSION SPAN OVER EAST RIVER, NEW YORK, NEW YORK

Island, where one branch goes west into Manhattan at 125th Street and the other north to the Bronx,—the Manhattan branch crossing the Harlem River with a vertical lift span of 310 feet span and of unusually handsome design, while the Bronx division crosses the Bronx Kills with a fixed span so built that it can be converted into a vertical lift span in the future.

The intersection on Randalls Island has been elaborately worked out to facilitate traffic to the greatest extent practicable, consisting essentially of a combined through roadway north and south, with a traffic circle of 265 feet radius for the Manhattan traffic, constituting an instructive example of modern thoroughfare design.

This bridge includes some 3¼ miles of bridge structure and 14 miles of approach boulevards, also instructive in regard to modern bridge design, and was executed at a cost of about $42,000,000.

The roadways of the lift spans have battledeck floors covered with mineralized asphalt plank.

Its two 43-foot 6-inch roadways are estimated to have a yearly capacity of about 20,000,000 vehicles. This project has been carried out by the Triborough Bridge Authority of which O. H. Ammann is chief engineer; Edw. W. Stearns, assistant chief engineer; Allston Dana, engineer of design; J. C. Evans, engineer of approaches; H. W. Hudson, engineer of construction; and Aymar Embury, II, architect.

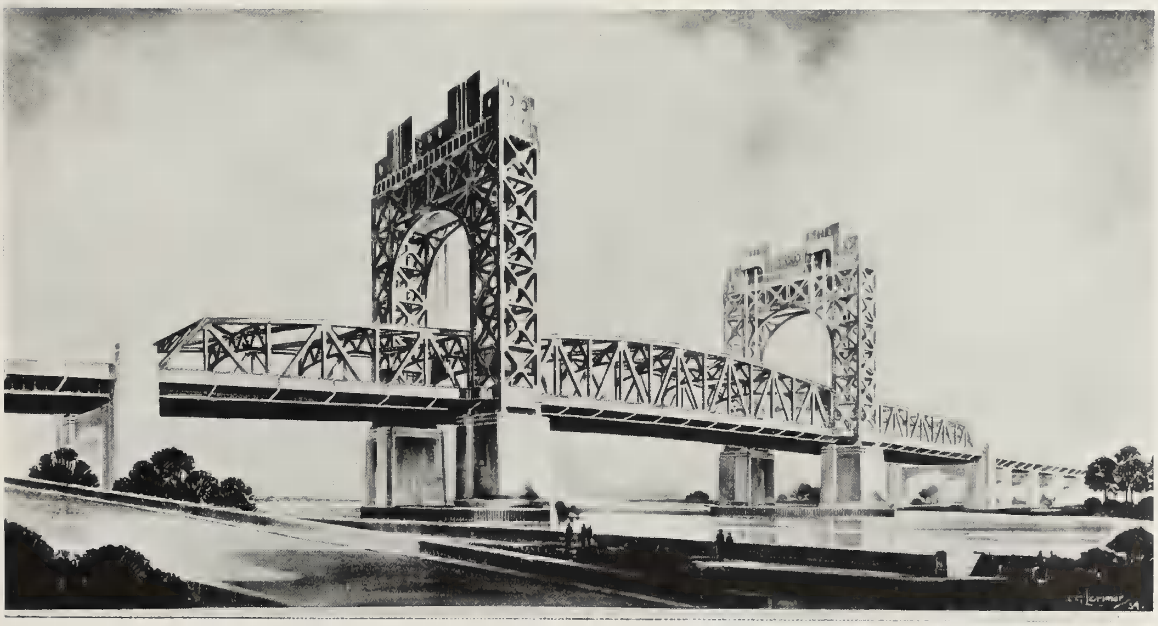


Figure 56. HARLEM RIVER CROSSING, TRIBOROUGH BRIDGE, NEW YORK CITY
Triborough Bridge Authority, O. H. Ammann, Chief Engineer
Ash-Howard-Needles & Tammen, Consulting Engineers

The consulting staff included Leon S. Moisseiff, Daniel E. Moran, and Chas. P. Berkey.

OHIO STATE HIGHWAY BRIDGES

During the past decade a number of notable highway bridges have been built by the various State Highway Departments. A considerable number of these are described and illustrated separately.

The work done by the State of Ohio, under Mr. J. R. Burkey, Bridge Engineer for the State Highway Department, is, we think, worthy of especial note. The Lorain Road Viaduct near Cleveland, separately described, is the work of that department, and the two structures now illustrated, the Bascule Bridge at Port Clinton and the Brook Park Viaduct near Cleveland, show a commendable effort to make these widely different types attractive as well as utilitarian. The Port Clinton Bridge is too overloaded with pylons, but nevertheless a move in the right direction.

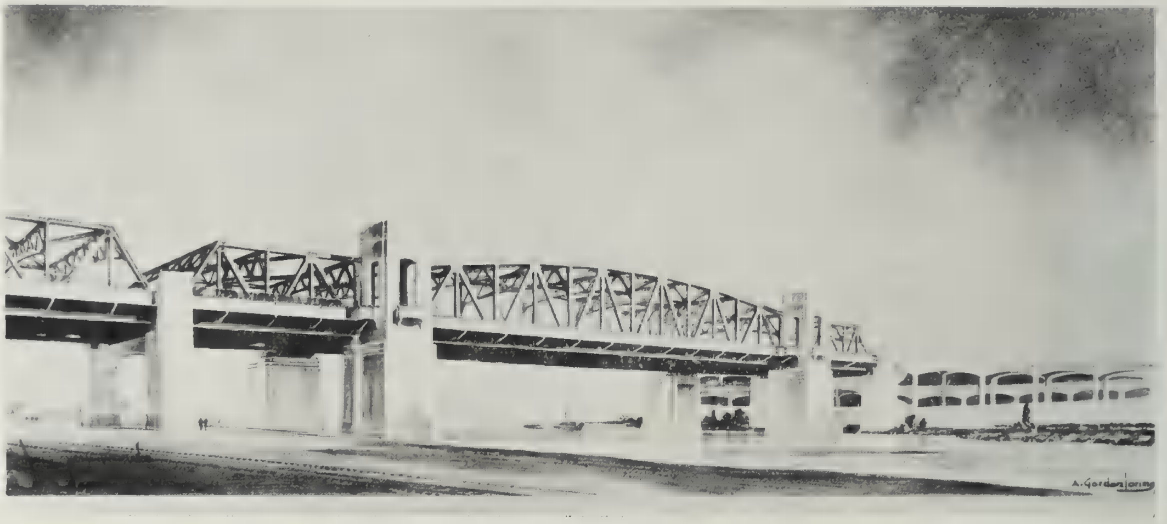


Figure 57. BRONX KILLS CROSSING, TRIBOROUGH BRIDGE, NEW YORK CITY
Triborough Bridge Authority, O. H. Ammann, Chief Engineer
Ash-Howard-Needles & Tammen, Consulting Engineers

OREGON STATE HIGHWAY BRIDGES

The State of Oregon is now (1936) completing a series of unusually large and fine bridges on the Oregon Coast Highway. These structures involve no radically new features, but are notable not only for their size but for intelligent treatment of both engineering and architectural features. The bridge over the Yaquina River comprises a 600-foot steel arch of the partly-through type, with a total length of bridge of 3,260 feet, the approach spans being mostly steel deck-girders. A clearance of 133 feet over the river is provided. The bridge over Alsea Bay has a total length of 3,028 feet and includes three reinforced concrete

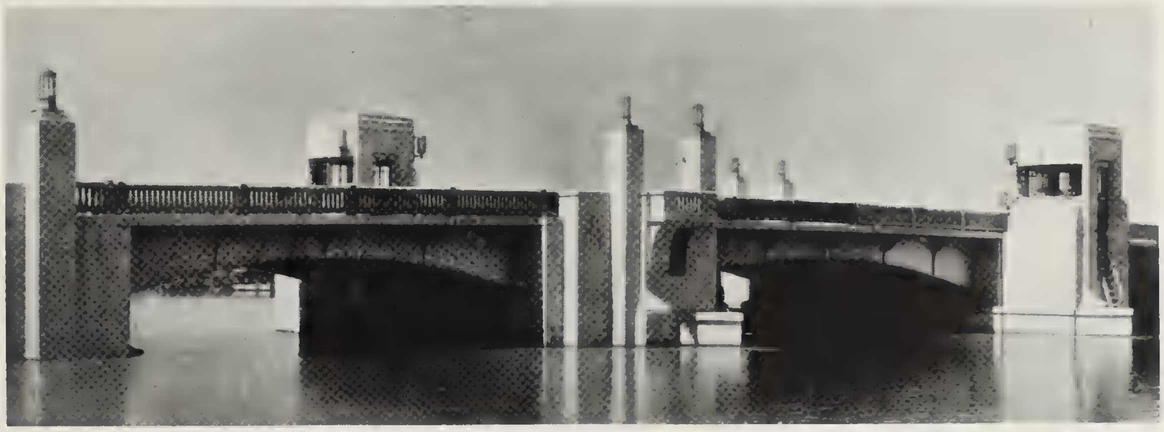


Figure 58. STATE HIGHWAY BRIDGE OVER PORTAGE RIVER, PORT CLINTON, OHIO—1935

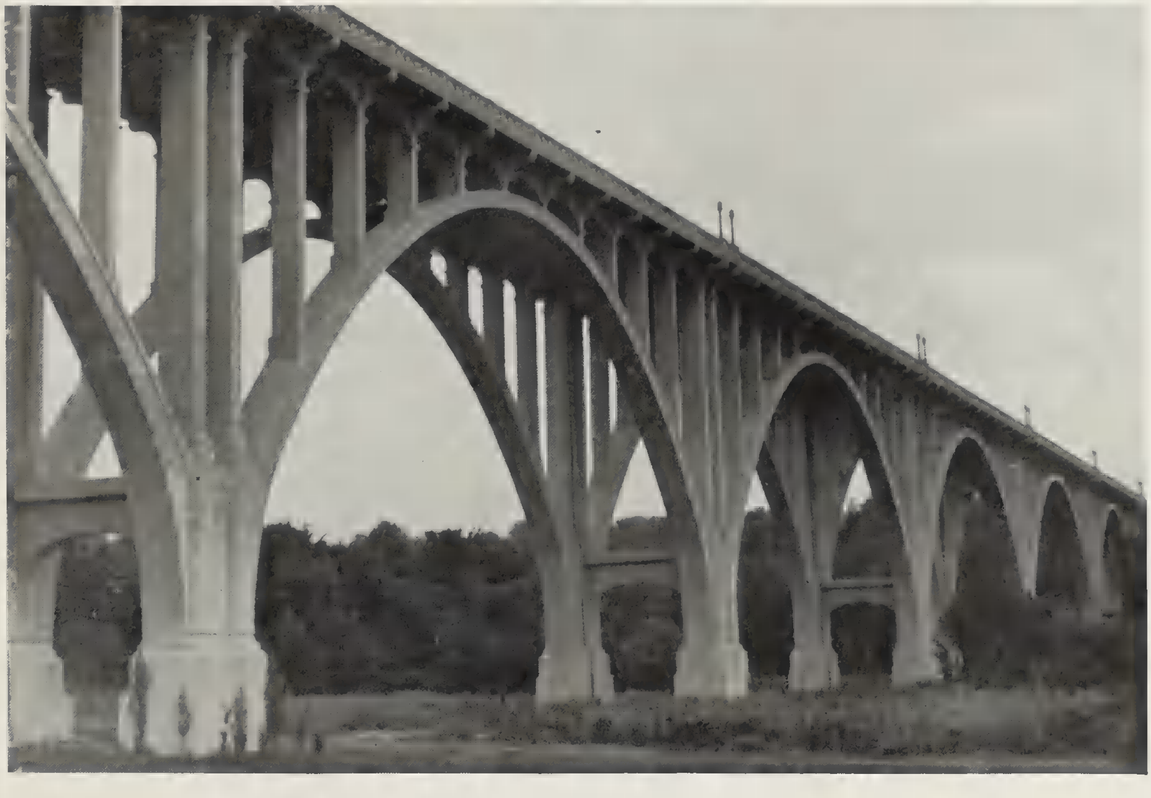


Figure 59. BROOK PARK VIADUCT, CLEVELAND, OHIO
OHIO STATE HIGHWAY DEPARTMENT

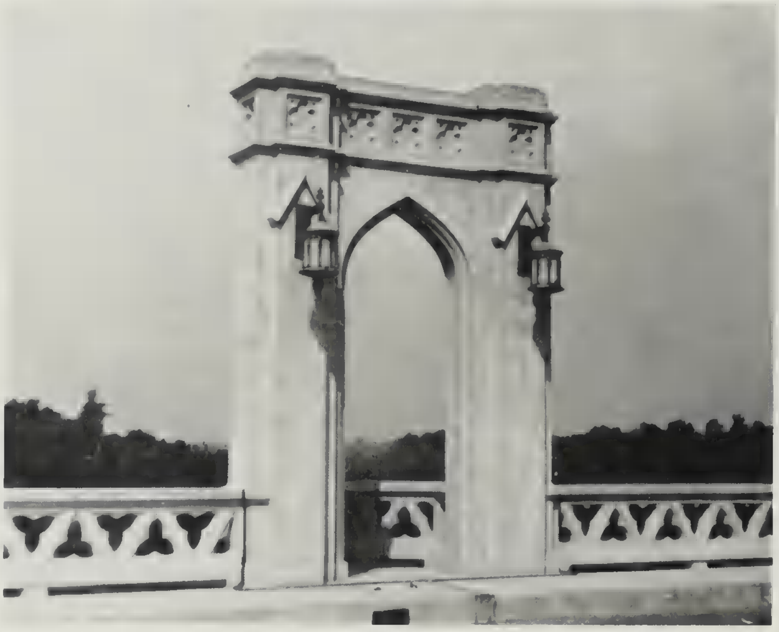


Figure 60.
PYLON—BROOK PARK VIADUCT
Ohio State Highway Deparment

tied arches of 210 and 154 feet span with concrete arch and beam approaches. The clearance over the bay is 70 feet. The span over the Suislaw River, with a total length of 1,650 feet has a bascule opening 140 feet clear, with one 154-foot concrete tied arch on each side and concrete approaches. The Umpqua River Bridge contains a swing span 430 feet in length flanked by two concrete tied arches on each side and a long concrete deck approach on one side, making the length over all 2,213 feet. The bridge over Coos Bay contains a cantilever of pleasing outline and 793 feet span center to center of piers, with 457½-foot anchor arms and concrete arch approaches. The total length is 5,337 feet. The overhead clearance is 120 feet for a 527-foot wide opening.

Distinctive features of these bridges are (a) the use of "Considere hinges" consisting of precast blocks of high-strength concrete placed on the axis of the arches during construction at the crown and haunches, thus greatly reducing secondary stresses in the arch ribs; (b) the use of hinges or rockers on short columns connecting the arch ribs with the concrete deck, thus reducing the restraining action of the deck on the arch ribs; (c) the use of concrete tied arches, the tie consisting of steel eye-bars encased in concrete, and the arches supported on steel shoes, the one end being provided with expansion rollers. A quite unique feature is the transverse bracing of the steel cantilever span of the Coos Bay bridge, the braces forming a series of Gothic or pointed arches.

Another notable Oregon structure is the Rogue River Bridge which is briefly described later.

The designs for these bridges were made by the engineering staff of the Oregon State Highway Department, C. B. McCullough, Bridge Engineer.

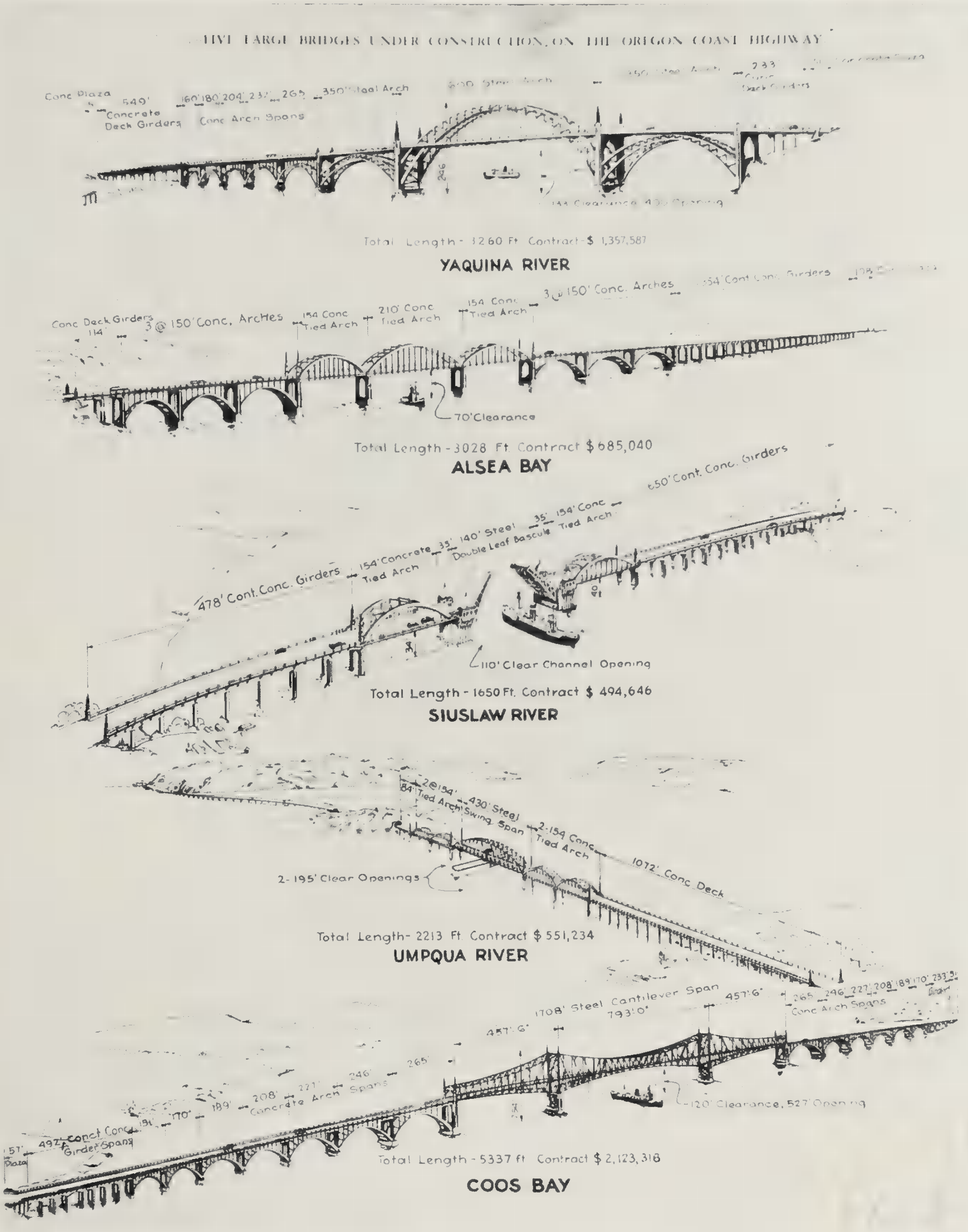


Figure 61. FIVE OREGON STATE HIGHWAY BRIDGES

PADUCAH, KENTUCKY, HIGHWAY TOLL BRIDGE OVER THE OHIO RIVER

Opened for traffic on April 14, 1929, this bridge crosses the Ohio where its normal width is about 4,000 feet. The structure is 9,000 feet long and comprises seven spans, 396 feet in length, one 514, and one 716 feet, all of the riveted type. The roadway is 20 feet wide and the pavement is a 6-inch concrete slab. Engineers—Harrington, Howard and Ash.

PHILADELPHIA, PENNSYLVANIA, TACONY-PALMYRA BRIDGE OVER THE DELAWARE RIVER

This publicly owned toll bridge crosses the Delaware above Philadelphia and comprises a 551-foot tied steel arch and a bascule span of 281 feet. The roadway width is 28 feet and the sidewalks are 4 feet 6 inches wide. Modjeski, Masters and Chase were the engineers.

PARIS, FRANCE, THE NEW PONT DE LA TOURNELLE

This bridge occupies the site of one of the ancient bridges over the Seine at Paris, replacing a stone arch structure completed in 1654.

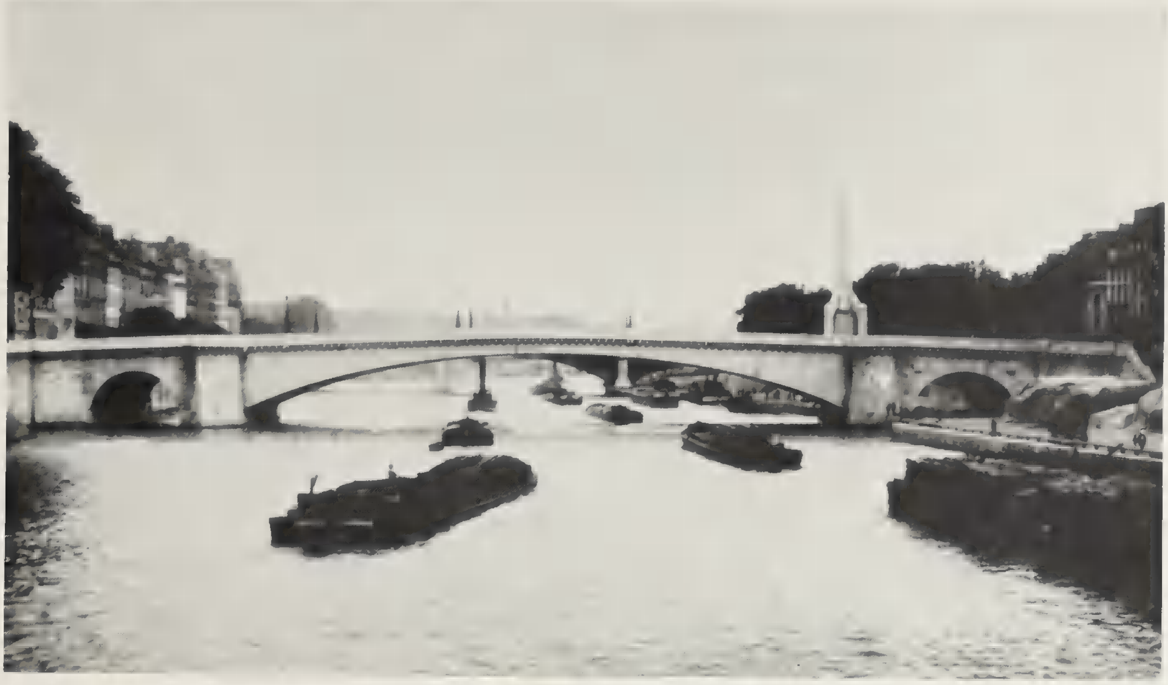
The new bridge is of reinforced concrete faced with limestone, built in 1928, under the direction of Lucien Deval, Chief Engineer of Bridges and Roads, and Henri Long, assisted by Pierre and Louis Guidetti, architects, and Paul Landowski, sculptor. The span of the main arch is 243 feet with a rise of only 23 feet. The only decoration, and that quite unusual, is the single shaft, supported carved figures and braced by flying buttresses carried across the roadway.

PHILADELPHIA, PENNSYLVANIA, CAMDEN BRIDGE OVER THE DELAWARE RIVER

After more than one hundred years of agitation, the bridging of the Delaware River at Philadelphia was finally accomplished in 1926. The ferry traffic between Philadelphia on the west side and Camden on the east side of the river had been steadily growing until it had reached great proportions, and the demand for a bridge became more and more insistent. This bridge, which held the world's record for length of span when built, was financed by the States of Pennsylvania and New Jersey, the half paid by Pennsylvania to be divided between the State and the City of Philadelphia. Work started in 1922, the cornerstone of the Philadelphia anchorage was laid with appropriate ceremonies on December 12, 1924, and the bridge was opened for traffic July 1, 1926.

Physical Data:

Length of main span—1,750 feet.
Length of bridge and approaches—9,570 feet.
Height of towers above water—380 feet.
Clearance above mean high water—135 feet.



Figures 62, 63.
PONT DE LA TOURNELLE
PARIS, FRANCE

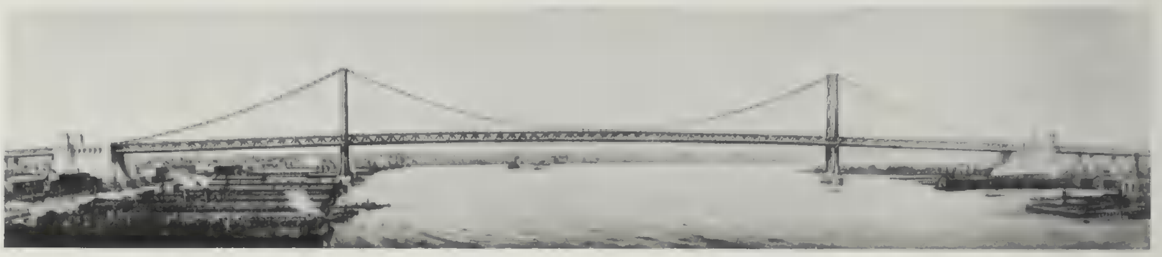


Figure 64. PHILADELPHIA-CAMDEN BRIDGE 1926
Ralph Modjeski, Chief Engineer. Paul P. Crét, Architect

Deepest foundation below mean high water—105 feet.
Width of roadway—57 feet.
Width of bridge—128 feet.
Diameter of cables—30 inches.
Masonry—315,000 cubic yards.
Structural steel—61,700 tons.
Cables—7,000 tons.
Cost approximately 36 million dollars, including purchase of land.

Personnel:

Board of Engineers—Ralph Modjeski, chairman, Geo. S. Webster, Lawrence A. Ball.
Principal Assistant Engineer—Clement E. Chase.
Engineer of Design—Leon S. Moisseiff.
Architect—Paul P. Crét.
Consultant on Foundations—Daniel E. Moran.

Engineering Data:

The outstanding engineering items of interest in this bridge include (a) the use of two cables only for such a long and heavy span, (b) the completion of the work on schedule time and without serious accidents to the work, although thirteen men lost their lives, mostly by falling, in spite of the greatest care. Among these was Mr. Clement E. Chase, Principal Assistant Engineer, one of the most noted of the younger members of the profession. The caissons for the towers were of timber and concrete 68 feet 8 inches by 143 feet in size and carried to depths of 75 feet on the west side and 110 feet on the east side of the river, by the pneumatic method. The caissons for the anchorages were reinforced concrete, sunk to rock by open dredging.

Architectural Data:

The items of architectural interest are chiefly the supporting of the approach or land spans between the towers and the anchorages on the bridge cables; the placing of the stiffening trusses below the cables, both of which contributed to the beauty of the structure; the graceful proportions of the towers; and the

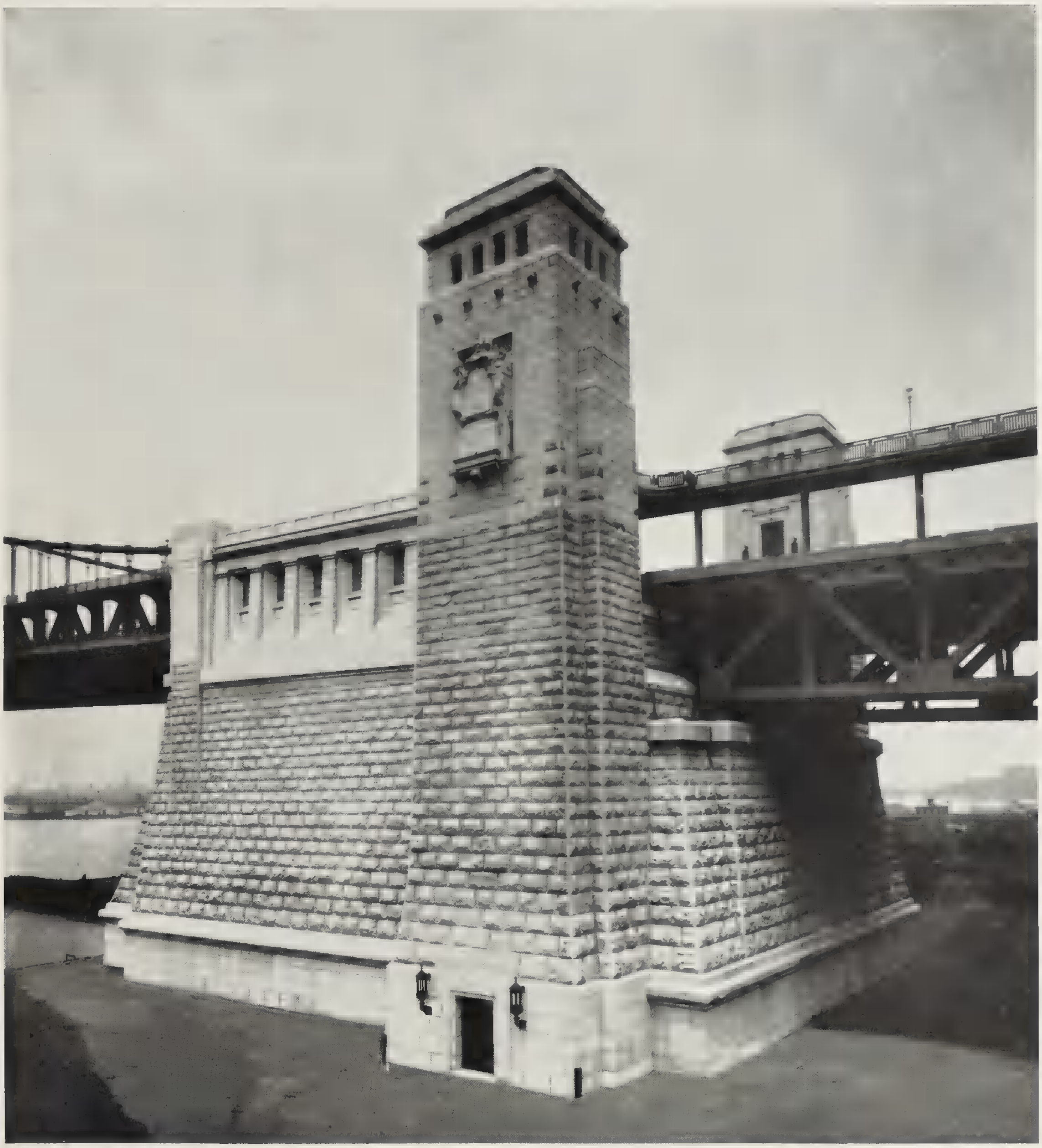


Figure 65. DETAIL OF ANCHOR PIER, PHILADELPHIA-CAMDEN BRIDGE

design of the massive granite anchorages. In the use of deliberate and conscious ornament, the architect has been sparing. In this connection especial mention may be accorded to the sculptured arms of the cities of Philadelphia and Camden, the Commonwealth of Pennsylvania and the State of New Jersey, which adorn the anchorage towers; the bronze lamps of the anchorage towers; the grilles of fretted granite beneath the anchorage parapets, the gilded grilles at the tops of the towers and the metal anchorage doors; and finally, the gilded figures of winged victory surmounting flag masts at each end of the bridge and supported on bases of dignified and convincing design. The treatment and expression of the sculptured coats of arms was developed by Mr. Leon Dermant, sculptor.

Traffic:

The traffic over this bridge has greatly exceeded the estimates, reaching a total of 12,308,225 vehicles in 1931. It is estimated that the entire cost of the structure can be paid off from net earnings in about seventeen years, or seven more years after 1936, and the bridge will then be free of tolls.

As an interesting study of traffic tendencies, the report of the Commission for the year 1935 shows that over ten million vehicles passed over this bridge during that year, including eleven horse-drawn vehicles, two horses and riders, and not a single led animal. About $10,000,000 additional was spent on the bridge during 1935 to provide for rapid transit cars, making the total investment about forty-six and one-half million dollars.

PHILADELPHIA, PENNSYLVANIA, PENNSYLVANIA RAILROAD BRIDGES

In connection with the construction of its new passenger station at Philadelphia, the Pennsylvania Railroad Company carried out extensive improvements to its bridges over the city streets, and the Company's engineers called in an architect, Mr. Paul P. Crét, who has been connected with the design of many bridges in a similar capacity, to assist in the design. The result of this collaboration is well shown by the illustration.

PITTSBURGH, PENNSYLVANIA, RECENT BRIDGES

It is said that Allegheny County, Pennsylvania, in which the city of Pittsburgh is located, has more bridges per square mile than any other place in the world. In order to meet the clearance requirements of its three rivers, as improved for navigation, it has recently become necessary to rebuild many of the older bridges, even though they were still serviceable; consequently the County has completed some very fine new bridges over the Allegheny, the Monongahela, and the Ohio Rivers. Worthy of note among these structures over the Allegheny are those at Fortieth Street, Thirty-first Street, Sixteenth Street, and the three suspension bridges at Ninth, Seventh and Sixth Streets.

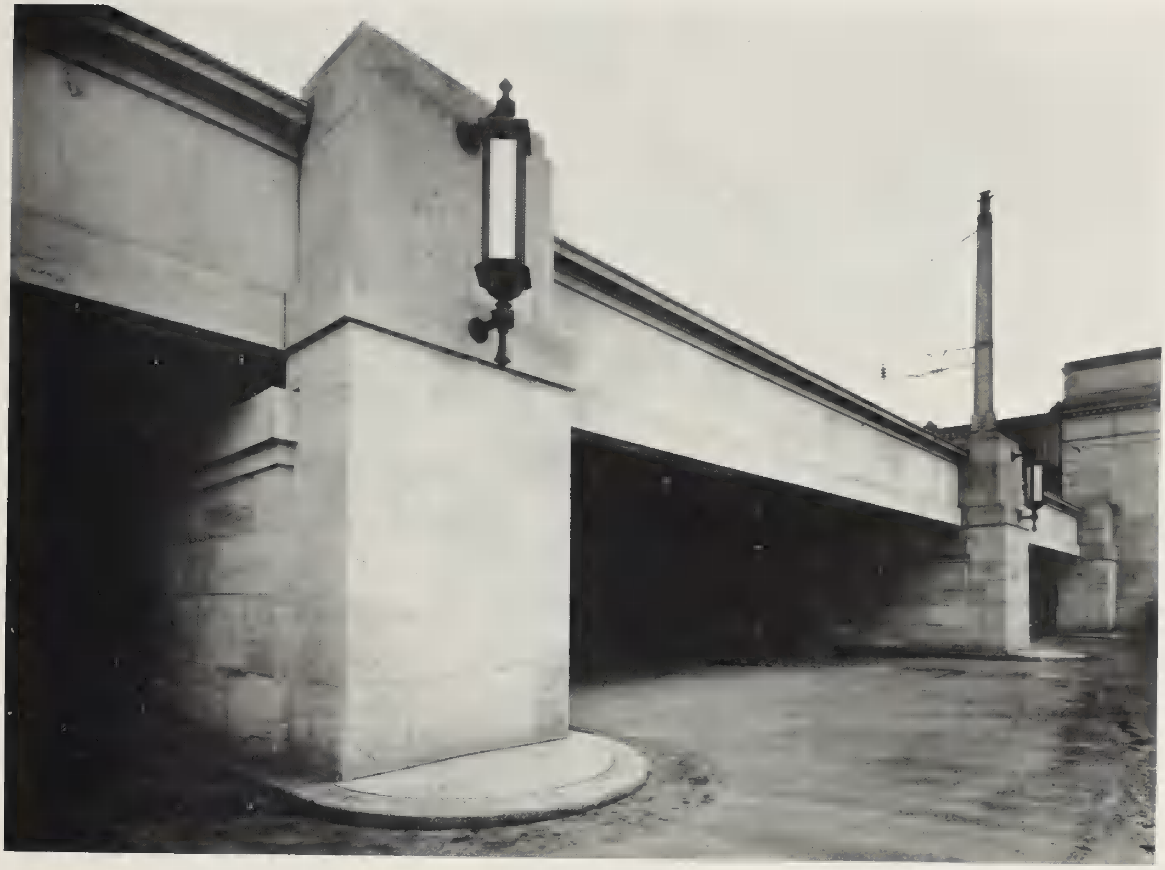
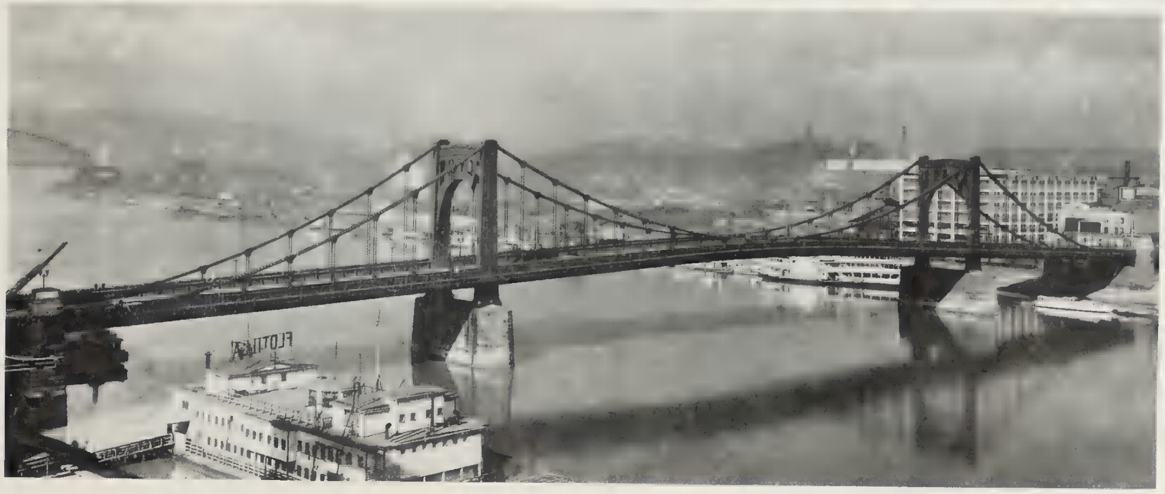


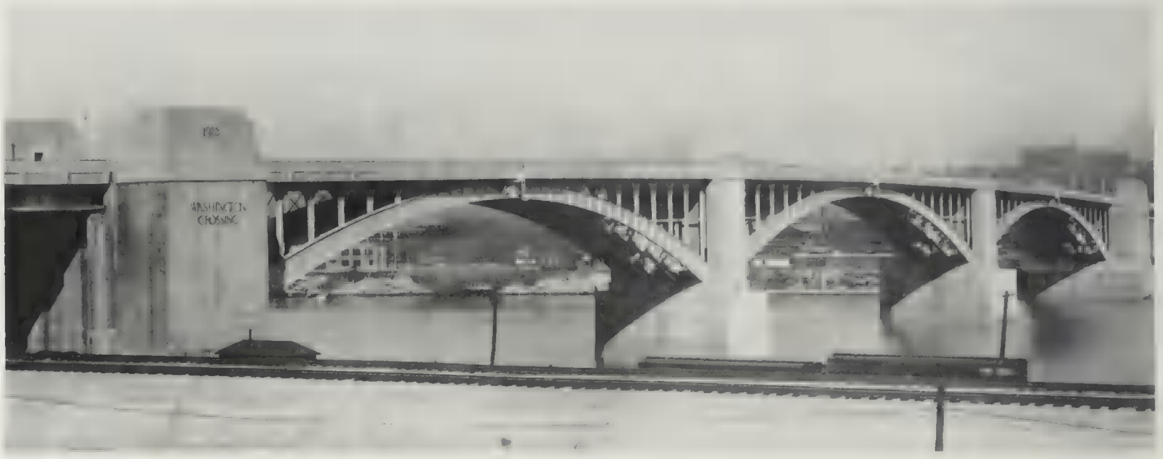
Figure 66. PENNSYLVANIA RAILROAD BRIDGE OVER 31st STREET, PHILADELPHIA, PA.



Photo, Courtesy Trinity Court Studio

Figure 67. SUSPENSION BRIDGE OVER THE ALLEGHENY RIVER, PITTSBURGH, PENNSYLVANIA
V. R. Covell, Chief Engineer

Those over the Monongahela River are at Clairton and at the "Point" where the confluence of the Allegheny with the Monongahela forms the Ohio. Over the Ohio River we find two recently constructed bridges of note, the West End-North Side Bridge and one at McKees Rocks. All of these new bridges at Pittsburgh are fine examples of engineering skill combined with art, for all are the result of collaboration between engineers and architects.



Photo, Courtesy Photo Products Co.

Figure 68. WASHINGTON CROSSING BRIDGE OVER THE ALLEGHENY RIVER, PITTSBURGH, PENNSYLVANIA

Janssen & Cocken, Architects. Charles Stratton Davis, Associate Engineer.

The handsome steel arch bridge at Fortieth Street, over the Allegheny, christened the Washington Crossing Memorial Bridge, was opened for traffic on December 29, 1924, on the 171st anniversary of the day George Washington crossed the Allegheny River accompanied by the guide, Christopher Gist, on his return journey from Fort Le Boeuf where he had been sent by Governor

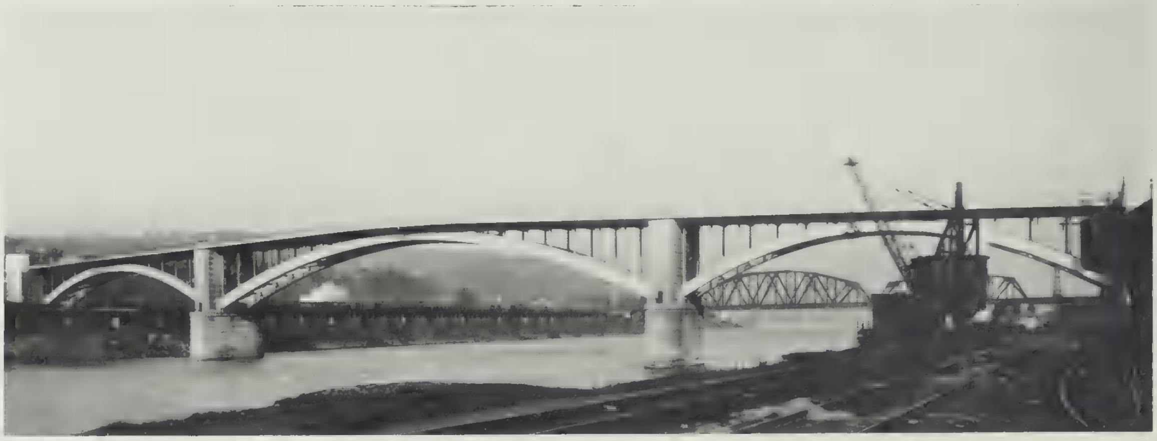
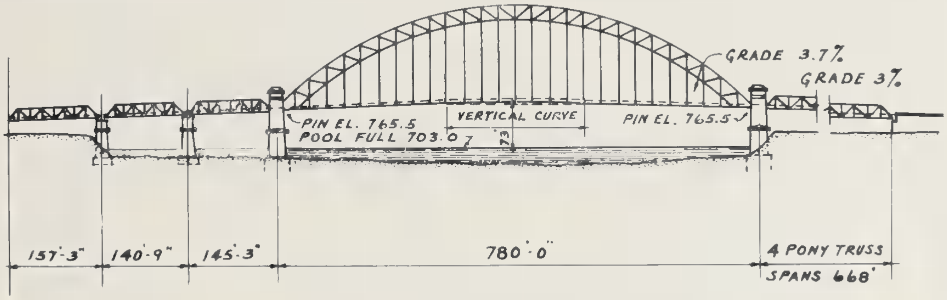


Figure 69. THE THIRTY-FIRST STREET BRIDGE OVER THE ALLEGHENY PITTSBURGH, PENNSYLVANIA—1918

Robert Dinwiddie of Virginia, on a special mission to confer with General St. Pierre in charge of the French forces in the West. While crossing the Allegheny River on a raft that he and his guide had built during the day, and while poling his way across the river, through running ice, Washington was thrown into the water but managed to escape to an island, later known as Wainwright's Island and now a part of the Pittsburgh shore, where he and Gist remained over night. On the following morning they crossed to the shore on ice that had jammed and frozen in the back channel over night. In addition to the name "Washington Crossing," placed on the faces of the two main piers, Colonial history is further commemorated by cast shields placed on the hand railings at intervals of about fifteen feet that bear the Great Seals of the original thirteen States and the Seal of Allegheny County, Pennsylvania.



WEST END-NORTH SIDE BRIDGE OVER THE OHIO RIVER
PITTSBURGH PENN.

Figure 70A

That portion of the bridge over the river consists of three graceful spans of steel arches supported by concrete piers, founded on rock at about 42 feet below pool level. The central span provides for a navigable channel 350 feet wide, and each of the flanking spans for one of 318 feet. The viaduct spans are of steel-deck, plate-girder construction resting on concrete piers and abutments. Four of these piers are founded on reinforced concrete piles and all others on natural soil, either clay or gravel. This bridge has a total length of 2,630 feet and provides for a roadway 38 feet wide, paved with creosoted yellow pine blocks laid on a concrete base on a steel buckle-plate floor, and two sidewalks each 8 feet wide, consisting of reinforced concrete slabs.

Janssen and Cocken, architects, and Charles Stratton Davis, associate engineer, were the designers of this bridge. Plans were approved by J. G. Chalfant, deceased, and V. R. Covell, county engineers, Allegheny County.

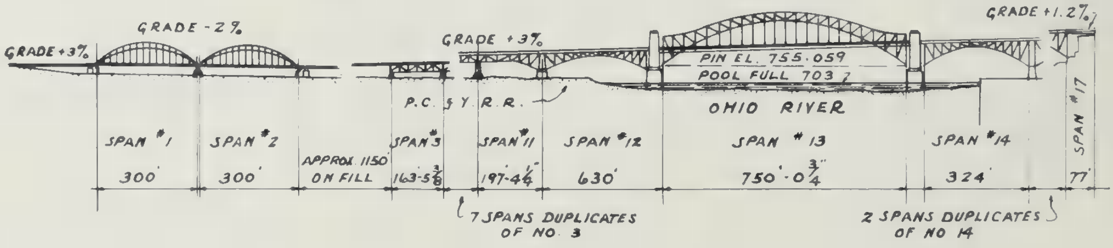
Architectural embellishments consist of the shields already mentioned, containing the Great Seals of the thirteen original States that are placed on the hand railings, the cartouches at the center of the three river spans, the bronze letters for the name of the structure, the brackets used to support the marine lights at the center of the river spans, and the bronze tables or nameplates. The modeling of the cartouches and shields was done by John Donnelly and Company of New York City. The entire project cost $2,810,000.

The Thirty-first Street Bridge comprises for the river crossing a center steel arch span of 380 feet 6 inches and 46 feet rise flanked by side arches of 229 feet span with 36 feet rise. The arches are of the deck type, the steel ribs of box construction, latticed on top and filled with heavy concrete containing scrap iron aggregate to obtain weight. These ribs support spandrel columns which carry the 32-foot wide roadway and the two 8-foot walks. The total length is 2,678.92 feet, including viaduct approaches.

Completed in 1928 at a cost of $1,400,000, this handsome structure was designed under the direction of V. R. Covell as chief engineer, with A. D. Mitter as designing and A. A. Henderson as construction engineers.

The bridge at Sixteenth Street, completed in 1923, consist of three tied steel arches of the overhead type, the center arch having a longer span than the two flanking ones. The beauty of the structure is largely the result of its general proportions as no attempt is made at decoration. The design is by Warren and Wetmore, architects, of New York, and H. G. Balcom, designing engineer. Plans were approved by J. G. Chalfant, deceased, and V. R. Covell, county engineers, Allegheny County. Daniel G. Moran served as consultant on foundations.

The three bridges over the Allegheny River at Sixth, Seventh and Ninth Streets are the most interesting of recent Pittsburgh bridges, on account of their unique design. They are all alike, differing only slightly in length of spans. These structures are of the so-called self-anchored suspension type, first exemplified in a bridge over the Rhine, at Cologne in Germany,—the distinctive feature of which is the elimination of the masonry anchorages to take up the tension on the cables at the ends of the bridge. This tension, or its horizontal component, is transmitted to the floor or stiffening girders, which thus act as a strut the full length of the bridge. These struts in the case of the Pittsburgh bridges carry a stress of about 5,000 tons. The German bridge mentioned was



McKEES ROCKS BRIDGE OVER THE OHIO RIVER
PITTSBURGH PENN.

Figure 70B

completed in 1915, has a center span of 605 feet, and two side spans of 302½ feet each, while the Pittsburgh bridges are somewhat smaller with center spans of 442 feet and side spans of 221 feet ½ inch. The roadways are 37 feet 6 inches wide, and walks 10 feet clear width. The height of the towers is 7 feet 11⅝ inches above water and the clearance over the river (pool level) is 47 feet.

These three bridges were designed by the Bureau of Bridges, Department of Public Works, Allegheny County, Pittsburgh, Pennsylvania, N. F. Brown, director, and under the supervision of V. R. Covell, chief engineer. C. J. Wilkerson was consulting engineer and A. D. Nutter, engineer of design. The plans were subject to approval by the City Art Commission of Pittsburgh.

The Pittsburgh suspension bridges have more pleasing proportions than their German prototype, brought about by the use of more massive towers and lighter chains and girders. All three use eye-bar chains instead of cables.

In the "American Architect" for February 5, 1928, Mr. Stanley L. Roush, A. I. A., who was connected with the development of the design, has the following to say: "The appeal to the layman and the thrill to the artist in the successful bridge design is largely psychic and consists of a peculiar mental reaction to the mechanics of the problem, as balanced by the esthetic rule of scale." Wm. Adams Delano, member of the Jury of Award of the American Institute of Steel Construction voices concisely the principles of aesthetic appeal in bridge engineering in his description of this structure: "The Sixth Street suspension bridge at Pittsburgh seemed to me in a singularly clear way to express the construction of the bridge without any unnecessary adornments. Unnecessary members which might have been put in for decorative effect were left out, yet the lines of the bridge were in themselves so good that the effect was most satisfactory."

The Allegheny River bridges had to be built with the shallowest possible floors in order to provide the clearance required by the Government without excessive grades. As finally built, these bridges have approach grades of 4.175 per cent.

The bridge over the Monongahela River between Glassport and Clairton is a steel cantilever structure of the deck type comprising a main center span and two flanking ones on each side. The unusual and distinguishing feature of this bridge is the use of curved lower chords on a cantilever truss, somewhat similar to those used on the Lorain-Carnegie bridge at Cleveland, Ohio. This bridge was completed in 1928, by Allegheny County, under the direction of V. R. Covell, bridge engineer.

The new "Point" bridge, replacing an eye-bar suspension bridge built in 1876 that became too narrow for modern traffic, consists of a single span steel arch with cantilevered ends of unusual design, in that the upper chord of the arch extends over the entire structure from portal to portal, whereas the lower chord spans the main opening only. This bridge has unique cast iron portals. It was

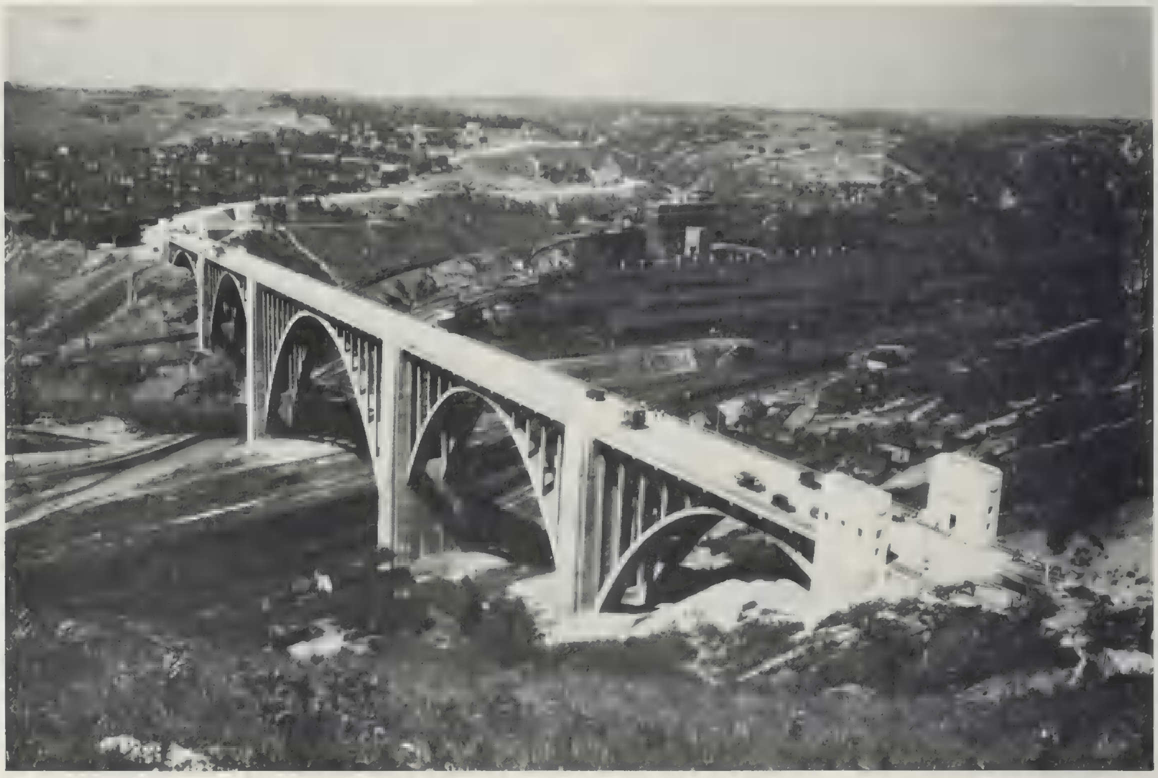
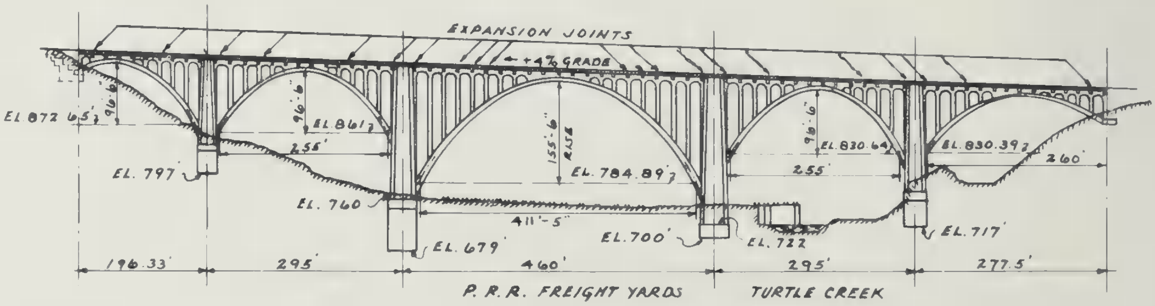


Figure 71. GEORGE WESTINGHOUSE BRIDGE, PITTSBURGH, PENNSYLVANIA
V. R. Covell, Chief Engineer



· ELEVATION · OF · GEORGE · WESTINGHOUSE · BRIDGE ·
· PITTSBURGH, PENNA.

Figure 72

opened for traffic in 1930. The main span is 670 feet in length, center to center piers, and the length over all is 1,330 feet. It carries a 38-foot roadway and two 12-foot walks outside of the trusses. The cost was $2,350,000. It was built for Allegheny County by the same staff that was responsible for the Sixth, Seventh and Ninth Street bridges, already described.

The West End-North Side bridge over the Ohio River, the first one below the confluence of the Allegheny and the Monongahela, about a mile distant therefrom, comprises a tied-arch of 780-foot span, flanked by "pony" or half through truss spans, providing a clearance over the pool level of 63½ to 73 feet. A tied-arch is one in which the end thrusts are resisted by a horizontal tie across the bridge, just as in the case of the so-called "self-anchored" type of suspension bridge used at Sixth, Seventh and Ninth Streets, where the horizontal pull of the suspenders is resisted by a strut carried across the bridge. In one case the tie is in tension, and in the other case it is in compression. The arches are of the parallel chord type and the hangers by which the floor system is supported from the arches are in the case of this bridge "prestressed" wire cables; that is, the cables are stressed before being used in order to obtain a uniform stretch. The bridge was built under V. R. Covell, Chief Engineer of Bridges, Allegheny County, and G. S. Richardson, Assistant. As in the case of all other bridges in Allegheny County costing over $25,000, the plans were subject to the approval of the City Art Commission.

The bridge at McKees Rocks, over the Ohio, is located at Nevilles Island, about six miles below the "Point," or confluence of the Monongahela and Allegheny Rivers, and is a long structure, some 5,510 feet in length, containing several notable spans. The one over the main channel of the Ohio is a spandrel braced steel arch, similar in design to the well known Hell Gate bridge at New York, of 750 feet ¾ inch span between centers of piers while over the west channel are two crescent arches of 300-foot span each, of the overhead type. This handsome bridge cost $5,160,000. Both of these Ohio River bridges carry 40-foot roadways and two 6-foot walks.

These Pittsburgh bridges are characterized by the use of steel for all load carrying parts of the superstructures, and by asphalt paved floors carried on buckle plates instead of the reinforced concrete slabs now quite commonly used.

The George Westinghouse Bridge over Turtle Creek Valley, just east of Pittsburgh, Pennsylvania, on U. S. Route 30, the famous and heavily traveled Lincoln Highway, now holds the record for long span concrete bridges in the United States, although it is exceeded in length of span by several European concrete bridges. These European concrete bridges of long span differ radically from the George Westinghouse bridge, which may be taken as a typical American design, in that the arch rings of the former are usually of hollow or cellular construction while the latter are solid sections. Cellular shafts are used for the piers, however, of the George Westinghouse bridge, as on many other American bridges. The total length of this structure is 1,510 feet and its height above the tracks of the Pennsylvania Railroad is 200 feet. The distinguishing feature of the bridge, however, is its main span of 425 feet clear opening. The main arch ribs have a theoretical span of 411 feet 5 inches and a rise of 155 feet 6 inches from the springing line. As shown by the illustration, the design is that known as the two-ribbed open-spandrel type, with massive piers carried up above the railing height. The roadway is 42 feet between curbs and there are two sidewalks each 7 feet wide. The roadway grade is 4 per cent descending westward. The foundations for this structure are on rock, at one point lying 85 feet below the surface. The two supporting ribs of the main span are 14 feet wide and 5 feet deep at the crown to 10 feet at the springing line. As is becoming more and more the custom, the mathematical computations of stresses in this arch were checked in the laboratory by means of small scale models, which are accurately constructed of celluloid, or similar material, and loaded with weights. The deflections are measured and it is possible then to compute the stresses. The accuracy with which stresses and strains can be determined by this method is one of the outstanding recent developments of bridge engineering science. Each rib of the main span of this arch is reinforced with 34 bars 1¼ inches square.

One of the chief arguments for building a concrete arch at this location, instead of a steel structure which could have been constructed at somewhat less cost, was that the concrete design was deemed preferable from an architectural standpoint, an argument that might be open to question in view of some of the more recent bridge designs carried out in steel and illustrated herein. At each end of the bridge are massive hollow concrete pylons which provide rooms for tools and caretakers, and the pilasters at the four intermediate piers are carried up well above the top of the metal railing. It is of interest to note the amount of concrete required in a modern bridge of this character; some 73,350 cubic yards were used in this, which cost approximately one and one-half million dollars, divided equally between the State of Pennsylvania and Allegheny County. This monumental bridge was built by Allegheny County, under the direction of N. F. Brown, Director of Public Works, and V. R. Covell, chief engineer, and was named after George Westinghouse, founder of the Westinghouse Company, whose principal works are located nearby. It was formally opened December 28, 1931.

PLOUGASTEL, FRANCE, BRIDGE OVER THE ELORN RIVER

This remarkable reinforced concrete arch bridge, opened in 1930, held the world's record for length of span of bridges of its type until the completion of the Esla River bridge in Spain in 1935, with its single unprecedented span of 627 feet. The Ploughgastel bridge, however, comprises three spans of 612-feet

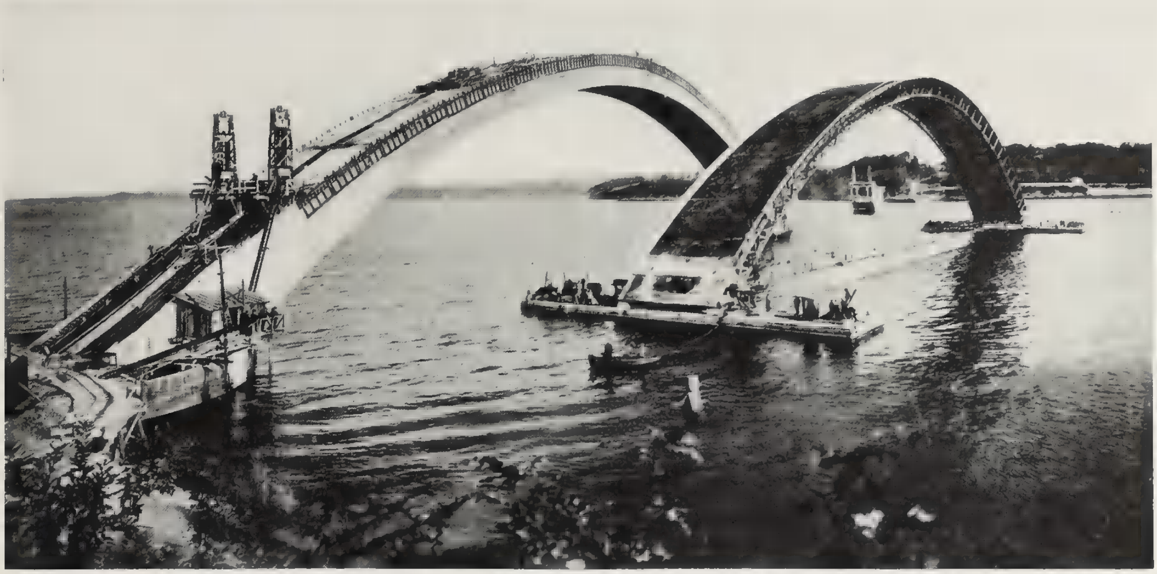


Figure 73. BRIDGE OVER THE ELORN RIVER, CENTERING, PLOUGASTEL, FRANCE

length. These arches carry a single track railway on a lower deck and a single roadway on an upper deck. The arch ribs are cellular in section, as are also those of the Esla River bridge and the Tranberg Sound bridge in Sweden with its span of 585 feet. The cells have four vertical walls with a maximum thickness of 3 feet. The arch concrete is composed of approximately one barrel of cement to two parts quartzite, one-half part sand residue and one-half part bar sand. It developed an ultimate compressive strength of about 8,500 pounds per square inch in one year. A working stress of 1,100 pounds per square inch was used in the design, much higher than is customary in the United States. In accordance with the methods developed by the designing engineer, M. Freyssinet, in connection with other bridges, these arches were provided with 28 temporary jacks at the crown, whose function was to force the arch ribs to take predetermined stresses before completing the crown section,—a method of controlling the stresses in arch ribs only recently introduced into the United States by Mr. C. B. McCullough in the design of the Rogue River bridge in Oregon. Most of the foundations are directly on the rock. The bridge is 2,864 feet in total length and cost about $450,000. The Limousin Company, well known French contractors, who built the great concrete airship hangars at Orly near Paris, also executed this work.

POINT PLEASANT, WEST VIRGINIA, BRIDGE OVER THE OHIO RIVER

This bridge, completed in 1928 by J. E. Griener & Company, engineers, is the first suspension bridge of the stiffened eye-bar type to be built in the United States. The design is somewhat similar to that of the suspension bridge at

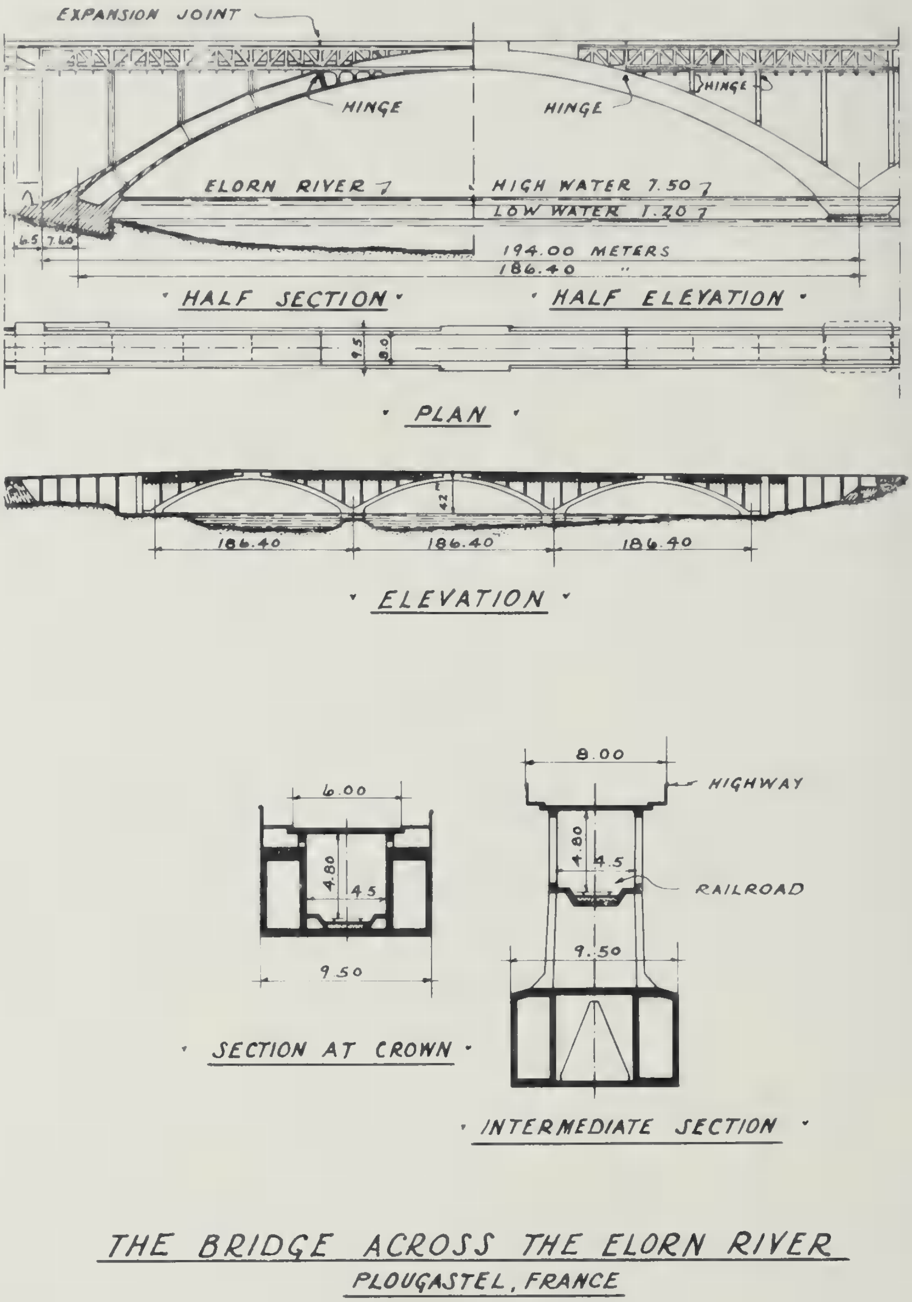

EXPANSION JOINT
HINGE
HINGE
HINGE
ELORN RIVER
HIGH WATER 7.50
LOW WATER 1.20
6.5
7.60
194.00 METERS
186.40 "
HALF SECTION
HALF ELEVATION
9.5
8.0
PLAN
42
186.40
186.40
186.40
ELEVATION
6.00
4.80
4.5
9.50
SECTION AT CROWN
8.00
HIGHWAY
4.80
4.5
RAILROAD
9.50
INTERMEDIATE SECTION
THE BRIDGE ACROSS THE ELORN RIVER
PLOUGASTEL, FRANCE

Figure 74.

Florianapolis, Brazil, already described. It is a highway bridge 2,235 feet long, comprising a suspended span 700 feet long over the river channel. The anchorages are unique because they are supported upon precast concrete piling.

The object of including this structure is principally to complete the illustrations of the various types of suspension bridges constructed during the last decade.

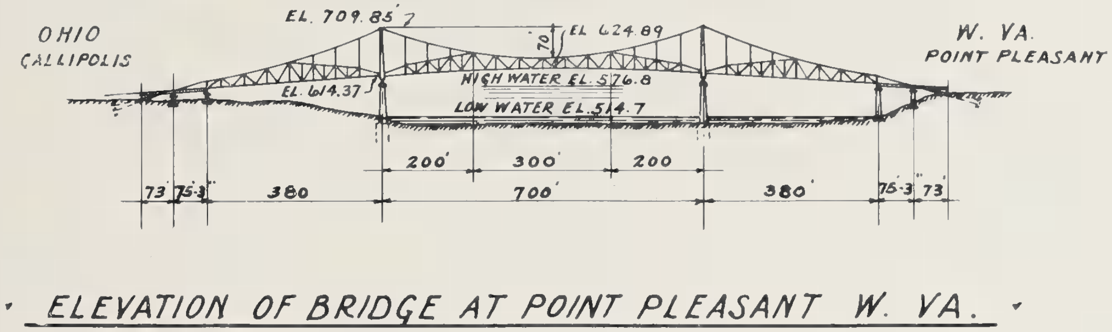


Figure 75.

POUGHKEEPSIE, NEW YORK, THE MID-HUDSON BRIDGE

This handsome highway bridge across the Hudson was opened for traffic in August, 1930, and cost approximately six and a half million dollars. It was built by the New York State Department of Public Works and comprises a main span of 1,500 feet between centers of piers, with side spans of 750 feet each. It is worthy of especial note because of its intrinsic beauty, and also because of the architectural treatment of its steel towers, entitling it to be called one of the world's most beautiful bridges. The roadway is 30 feet wide, and there are two sidewalks, placed outside of the stiffening trusses. Clearance above mean high

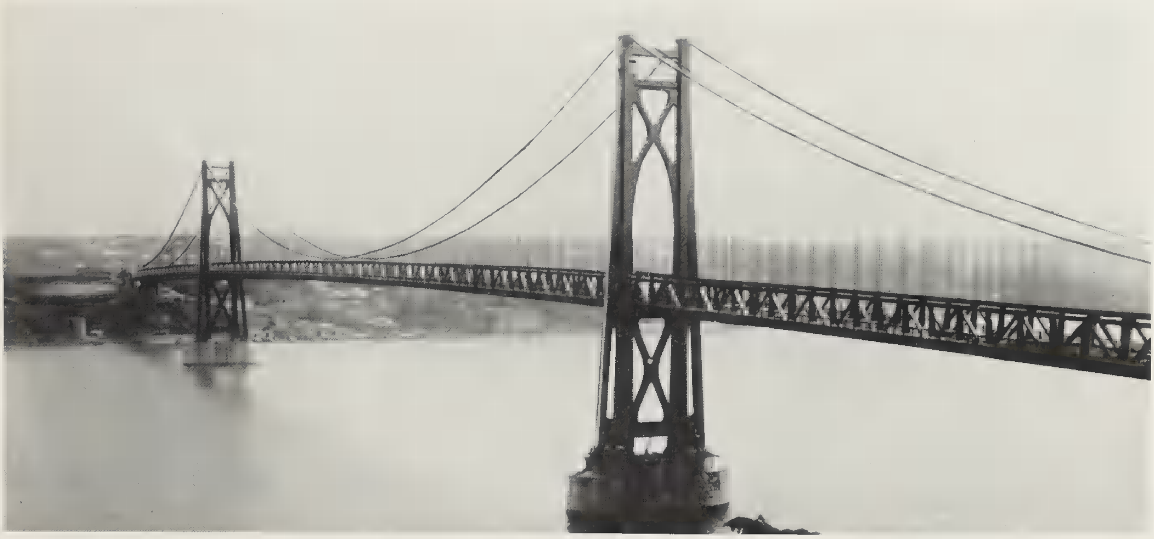


Figure 76. THE MID-HUDSON BRIDGE, POUGHKEEPSIE, NEW YORK

water is 135 feet. The two river piers are on caissons 60 by 136 feet in plan, sunk by open dredging to a depth of 135 feet below water. When the east pier reached a depth of about 84 feet it began to list and reached an angle of 43½ degrees out of plumb. It was righted by pulling with cables and by dredging to its correct position, quite an engineering accomplishment on the part of the Blakeslee-Rollins Corporation, the contractors. The two main cables are 16¾ inches in diameter, of the customary parallel wire construction, using wire having an ultimate strength of 215,000 pounds per square inch. Each cable has a maximum working load of 12,000,000 pounds. Natural rock anchorages were used. The towers are 280 feet high from the top of the masonry to the centers of the cables, of graceful outline, the bracing forming a sort of Gothic arch over the roadway. Inasmuch as the elongation of the cables, as the dead load came upon them, was computed to bring about a deflection of about 9½ inches at the tops of the towers, they were pulled back this amount during erection. In this type of suspension bridge, now almost universally adopted, the towers are flexible, that is without having hinges at their base they are sufficiently elastic to permit of a certain amount of lateral motion due to changes in the lengths of the cables.

This bridge was built under the direction of Fred S. Greene, Superintendent Department of Public Works of the State of New York, and Wm. M. Acheson, its chief engineer, and designed by Ralph Modjeski and Daniel E. Moran, consulting engineers.

PROVIDENCE, RHODE ISLAND, WASHINGTON STREET BRIDGE

Contains 12 reinforced concrete arches and a 150-foot bascule span. The arches are faced with granite. Engineer—C. W. Hudson, Architect—Carl L. Otto.

The total length of this bridge is 2,408 feet and it carries a 60-foot roadway and two 10-foot walks. It was opened for traffic on September 25, 1930, and cost nearly three million dollars. A monumental structure.

QUEBEC, BRIDGE AT ILE D'ORLEANS

This is a suspension bridge comprising a main span of 1,059 feet, and anchor spans of 417 feet 6 inches carried on 10-inch diameter cables of the prestressed strand type. Monsarrat & Pratley of Montreal were the engineers.

A steel grid floor with lightweight concrete is an unusual detail of the design.

RHODE ISLAND, THE MT. HOPE BRIDGE

This bridge was awarded a prize by the American Institute of Steel Construction as one of the most beautiful erected in the year 1929, and can be best described in the words of Dr. J. Horace McFarland, President of the Pennsylvania Art Commission: "The Mount Hope Bridge commended itself to the Jury because of its sheer grace, in the first instance, and because of the way in which the lines of the whole structure had been made sightly and attractive. But little needs to be said as to the way in which a long suspension span gives opportunity for graceful and natural lines, save that the designer of this bridge must have had very fully in mind the quality of beauty in addition to the essential factors of strength, stability and endurance. As one looked at the photographs of the bridge, particularly the one made at night when the light was concentrated on the long span sustained by suspension cables, there was the inevitable feeling of eye and mind satisfaction which an object of sheer beauty gives. The photographs of the details of this important structure added the necessary estimation of the strength, stability and capacity of the bridge and of the excellence of its simple but sightly approaches. Writing wholly as a layman in bridge engineering, and only from the standpoint of one who believes everything placed in the public eye should be designedly and simply beautiful, I can emphasize further the agreeable impression given in the photographs of the towers from which the long span is suspended. These towers give an impression of rugged strength and enduring stability, but also the gracious lines of the supporting members rising from the bridge floor have peculiar attractiveness. It was this, I think, as much as the general grace of the structure, which attracted the unanimous verdict of the Jury, including members competent, as I am not competent, to discuss the structural capacity and features of the Mount Hope Bridge. As one

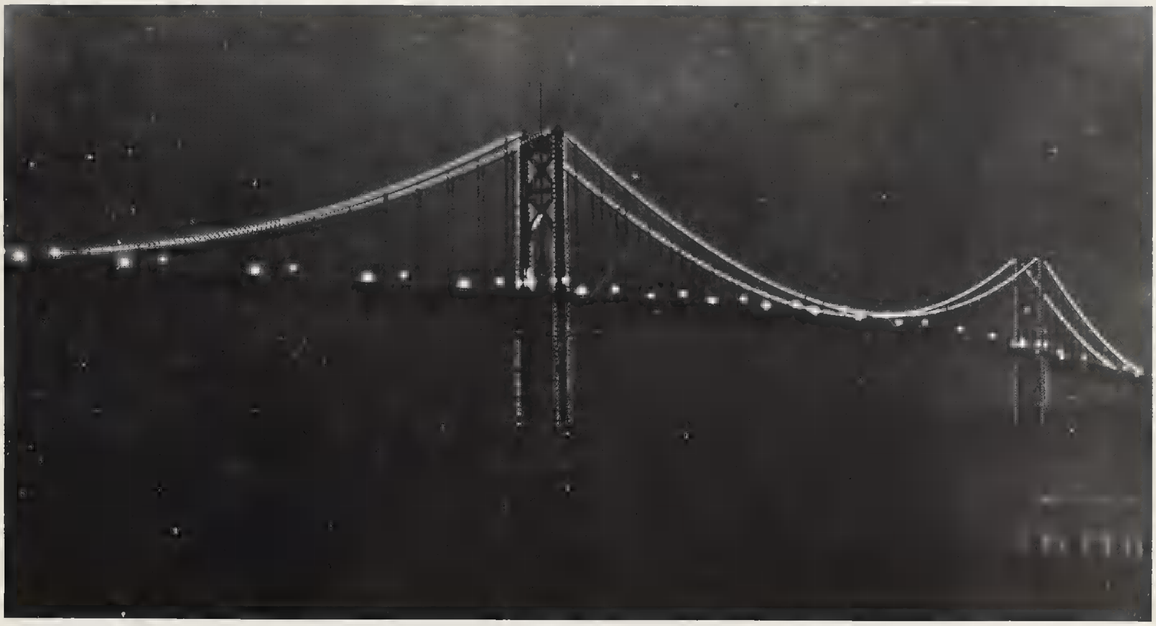


Figure 77. NOCTURNAL VIEW—MT. HOPE BRIDGE, RHODE ISLAND
Robinson & Steinman, Engineers. Theodore Blake, Architect

gazes through the bridge from one tower to another, again there is this feeling of great satisfaction that a utilitarian structure should give real pleasure to the beholder as well as deliver the designed service. The same considerations govern the treatment of the long span of the gently arched roadway, the supporting trusses of which merge into the towers almost insensibly. There is, too, as one looks at the masonry foundations, a feeling that here again more than strength was sought, for the line from the water surface to the top of these towers, including both stone and steel, is one of symmetry and beauty."

This bridge was opened to traffic on October 24, 1929.

Physical Data:

Length of suspended main span—1,200 feet.
Length of suspended side spans—504 feet.
Main towers—284 feet high.
Cables—Two, 11 inches diameter.
Roadway—54 feet; 2-foot safety walk.
Total length of bridge—5,010 feet.
Vertical clearance—135 feet.

Foundations about 60 feet maximum depth, on sand and gravel.

An unfortunate occurrence delayed the completion of this bridge. When the structure was almost completed, but before the concrete floor was in place, it was discovered that breakages were occurring in the wire cables at the anchorages. A new type of wire had been selected for this work; a heat-treated wire having an elastic limit of about 85 per cent of its ultimate strength instead of the 65 per cent characteristic of untreated wire. It was found necessary to dismantle the superstructure and rebuild the cables with untreated wire. A similar experience was had on the Ambassador Bridge at Detroit, at about the same time with the same type of wire, and bridge engineers were greatly puzzled by these failures, as the material had been very carefully tested and had met rquirements in such tests. After several years study on the part of the United States Bureau of Standards and others, it is now quite generally agreed that the failures were due to fatigue caused by fluctuating conditions of stress during construction operations, and that this particular type of wire was not well adapted to resist such conditions.

ROCHESTER, NEW YORK, THE VETERANS MEMORIAL BRIDGE OVER THE GENESEE RIVER

This quite unusual structure comprises a single full-centered arch of 300 feet span, flanked by three small arches on each side. The general exterior design is extremely simple, with no attempt at decoration of any kind. While the framework is entirely of reinforced concrete, the unique feature consists in the use of a facing on all exposed sides of sawn granite. This granite facing is from

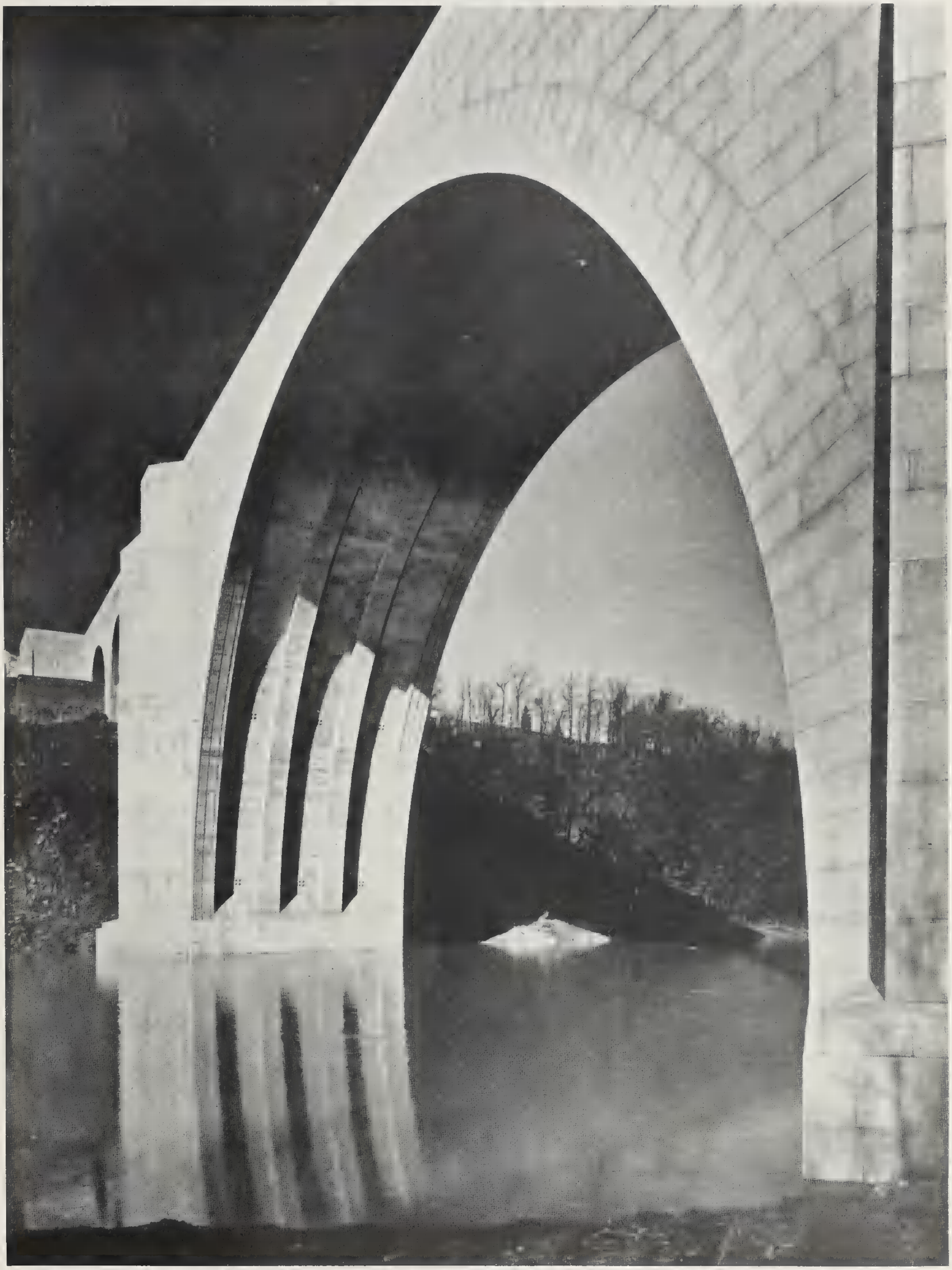


Figure 78. VETERANS MEMORIAL BRIDGE, ROCHESTER, NEW YORK
Frank P. McKibben, Construction Engineer. 1932 *Gehron & Ross, Architects*

four to twelve inches thick, placed as the concrete was poured and anchored thereto by metal ties. The surface of the granite slabs was left as it came from the quarry gang-saws. The main arch is composed of four reinforced concrete ribs, upon which the floor is supported by means of columns, beams and slabs; in fact, it is structurally an open spandrel reinforced concrete ribbed arch, although great pains and expense have been incurred in order to hide that fact. The arch ribs are connected by diaphrams at the soffits, giving the appearance from beneath of a solid barrel type arch with projecting ribs and the spandrels are closed by thin concrete walls faced with granite. The question may well be asked as to whether this is either good architecture or good engineering; it is not good economy. As a subject for photographic effect it is ideal, which is quite appropriate in a way as the great plant of the Eastman Kodak Company is nearby. The general idea, that of enclosing an essentially open spandrel arch with side walls and soffit slabs, has been used in many other recent structures. Some very handsome bridges at Munich, Germany, built about thirty years ago, are constructed this way, the false spandrel walls being in that case of native limestone, and similar details were employed in the construction of the Pont Butin, at Geneva, Switzerland, and the new Pont de la Tournelle at Paris. The Rochester bridge occupies a picturesque site, spanning the 175-foot deep gorge of the Genesee River, and is quite reminiscent, in general appearance, of the old Roman type.

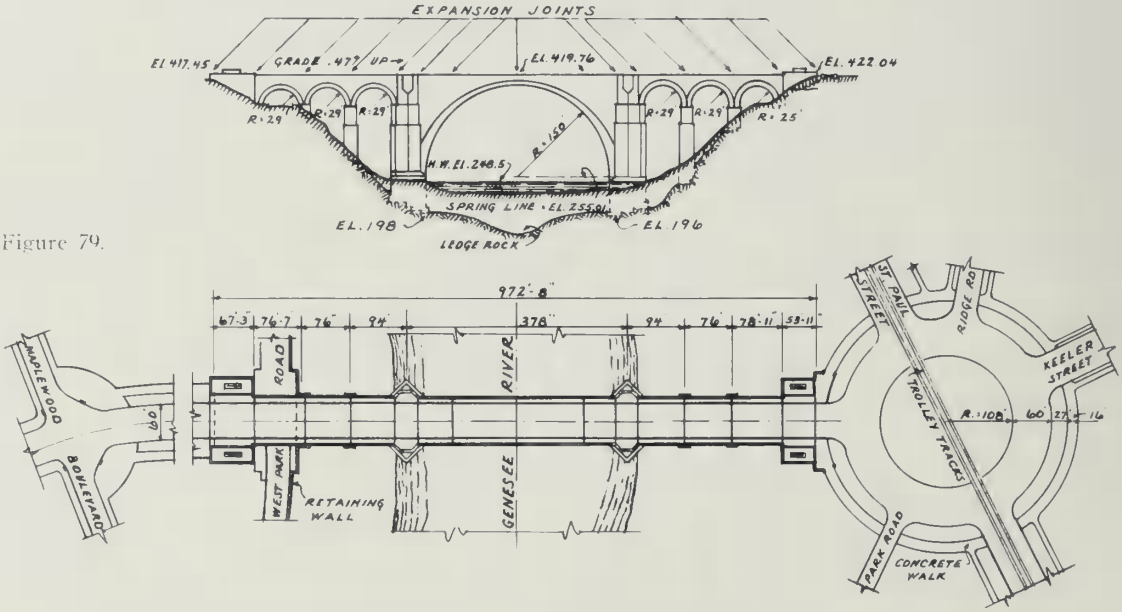
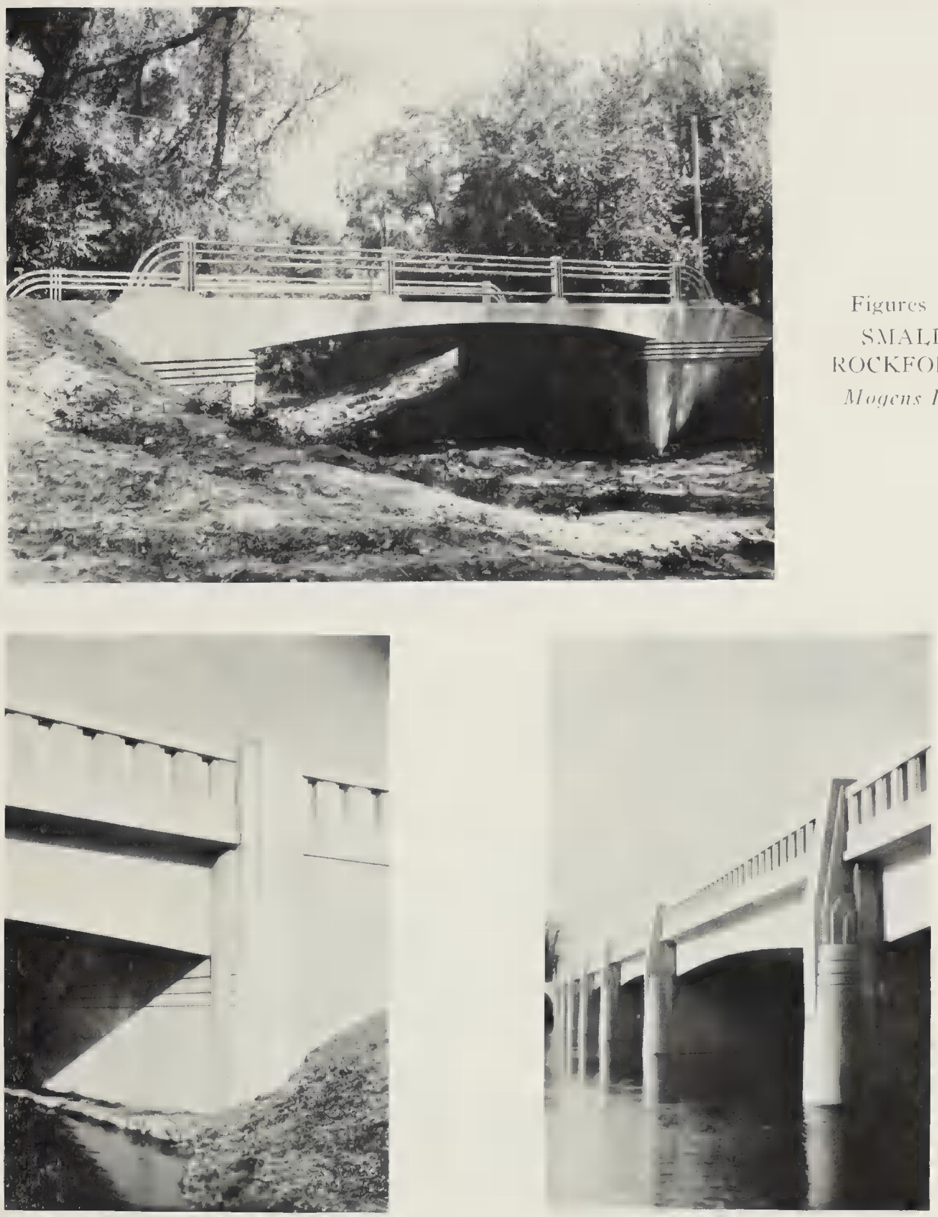


Figure 79.

· PLAN · & · ELEVATION · OF · VETERANS · MEMORIAL · BRIDGE ·

· ROCHESTER N.Y. ·

FRANK P. McKIBBEN, CONSULTING ENG. GEHRON & ROSS, ARCHITECTS



Figures 80A, 80B, 80C
SMALL BRIDGES,
ROCKFORD, ILLINOIS
Mogens Ipsen, Engineer

The length is 972 feet 8 inches over all and the cost about $3,000,000. The architects collaborating in the design of this beautiful bridge, Messrs. Gehron and Ross, were awarded the Architectural League of New York's Silver Medal in Architecture for their work in connection with this bridge and the Soldiers and Sailors Memorial Bridge at Harrisburg, Pennsylvania.

ROCKFORD, ILLINOIS, SMALL PARK BRIDGES

From among the great number of beautiful small bridges constructed during the past decade we have selected a few illustrations from the work of Mogens

Ipsen, of Rockford, Illinois, as exemplifying the influence of so-called "modernism" and "international style" upon bridge design as applied to the smaller structures.

We have previously illustrated one of Mr. Mogen's bridges at Freeport, Illinois, and many more similar structures have been designed by numerous engineers and architects serving municipalities, states, park boards and individual owners throughout the United States and Canada, the countries that, at present, seem to be taking the lead in the development of the artistic small bridge; and especially in the use of concrete for this purpose.

ROGUE RIVER BRIDGE, OREGON

In the construction of this bridge, built by the Oregon State Highway Department, the Freyssinet method of construction developed in Europe was first introduced in the United States. This method consists of the use of powerful jacks inserted at the crown of the arch ribs during construction in order to eliminate or reduce the rib shortening due to shrinkage of concrete, compression of dead load, etc. The Rogue River bridge comprises seven 230-

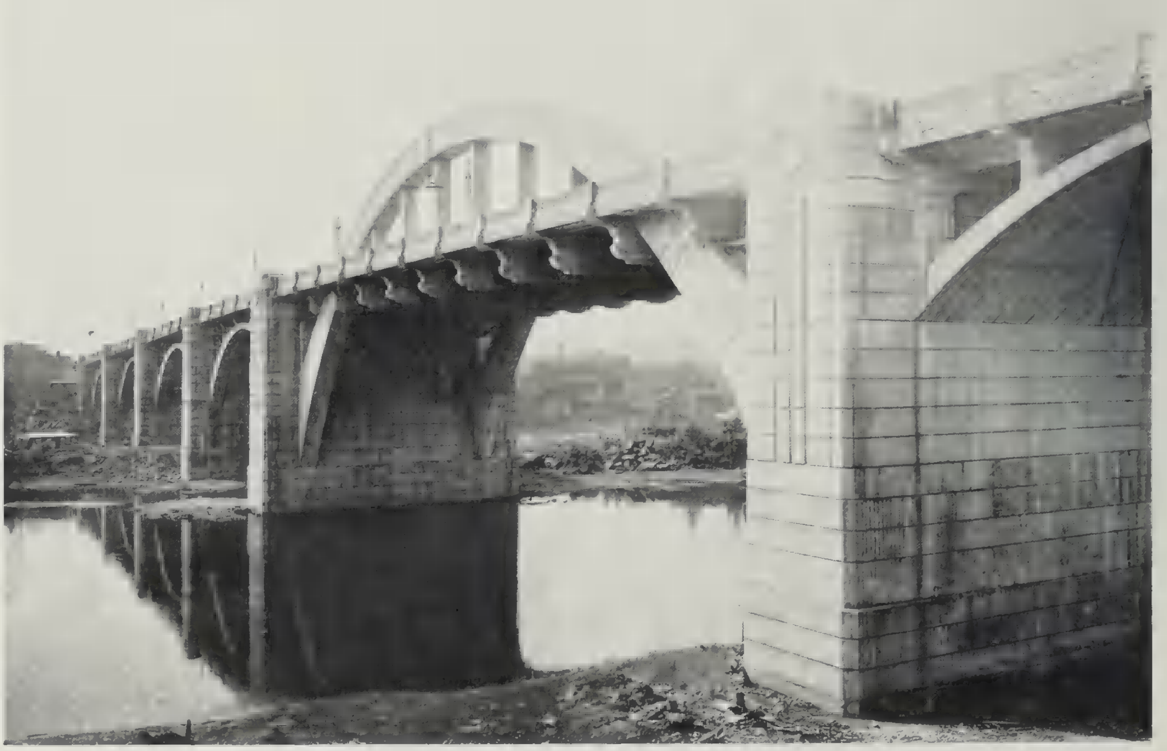


Figure 81. ROBERT STREET BRIDGE OVER MISSISSIPI RIVER, ST. PAUL, MINN.
Toltz, King & Day, Engineers and Architects
1926

foot open spandrel arches. The engineer in charge of this work was C. B. McCullough, bridge engineer for the Oregon State Highway Department.

ST. JOSEPH, MISSOURI

A two-span continuous truss highway bridge over the Missouri River, built in 1930. Each span is 450 feet 4 inches center to center piers in length. This interesting structure was designed under the direction of T. H. Cutler, chief engineer of the Missouri State Highway Department, and L. J. Severdrup, engineer of bridges, assisted by Robert Sailer, principal designing engineer.

ST. PAUL, MINN., ROBERT STREET BRIDGE

This is a structure of quite unusual design, using a combination of reinforced concrete and structural steel encased in concrete and embellished with a considerable amount of architectural detail, possibly too much.

The total length of the bridge is 1,100 feet while the main channel of the river is crossed by a clear span of 244 feet, a bowstring or half through arch

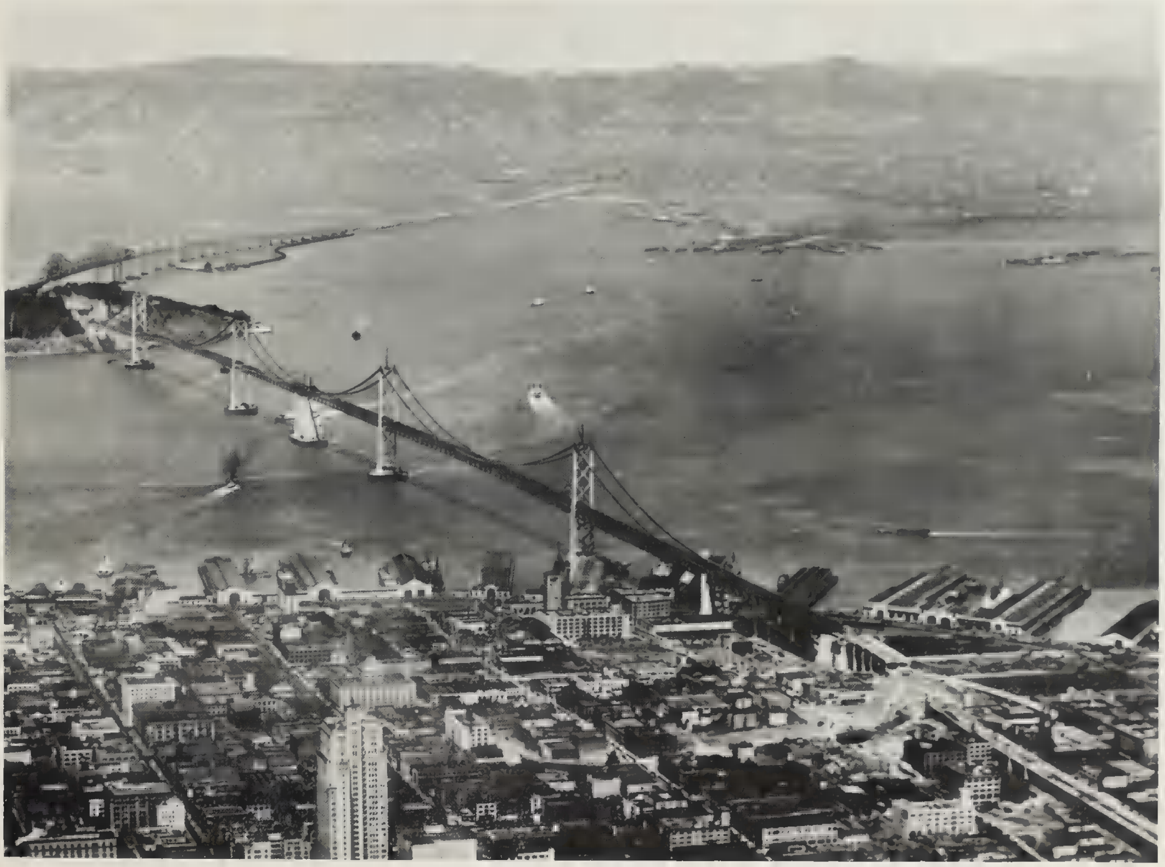


Figure 82. SAN FRANCISCO-OAKLAND BAY BRIDGE
1936

reinforced with structural steel from which the floor system of encased structural steel is suspended, the exposed ends of the floor beams presenting an elaborately fretted profile. The approach spans are of the deck type.

SAN FRANCISCO, CALIFORNIA, THE SAN FRANCISCO-OAKLAND BAY BRIDGE

Historical:

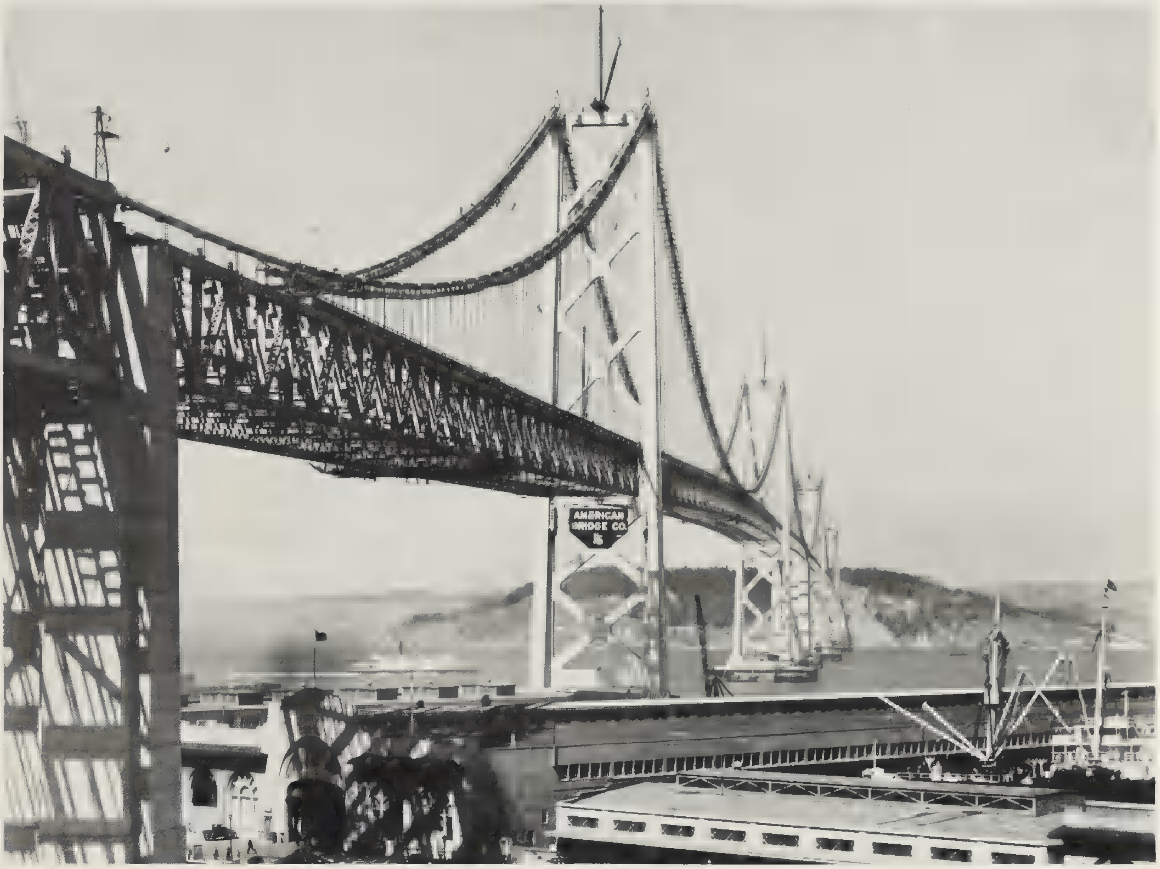
The City of San Francisco is situated on a peninsula lying between San Francisco Bay and the Pacific Ocean. In order to reach the city from the east it has been necessary to ferry across the bay. For some eighty years the problem of bridging the bay has been discussed, and many preliminary reports and plans have been made. In 1916 such a report was made to a committee of of the Chambers of Commerce of the cities of San Francisco, Oakland and Alameda by Messrs. Watson, Davis and Miller, who advocated a low level bridge with two draw spans to be located south of the present structure, with its eastern terminus in Alameda. Definite information regarding the nature and depth of the underlying rock was lacking, and the engineers' opinion was that traffic at that time did not warrant the tremendous expense of a high level, long span structure. San Francisco Bay is the only good large harbor of refuge for many hundreds of miles along the Pacific Coast, and the United States engineers frowned upon the project of a low level bridge, fearing that it would be a menace to the use of the harbor; so the project was abandoned at that time.

In 1921 a report was made by Ralph Modjeski and J. Vipond Davies upon the project, who favored the construction of a long-span, high level bridge substantially as now constructed. Surveys and soundings made in 1929 disclosed that rock foundations were actually nearer the surface at a point near to Yerba Buena Island than they were farther south, thus pointing definitely to the route selected as the most practicable for a long span. Moreover, the high bridge was finally determined to be the only type that could be built without serious interference with marine interests. A commission was finally appointed in 1929 by President Hoover and Governor Young to carry out the project. General Goethals had proposed that the ferry be continued to Yerba Buena Island and that a tunnel be constructed from the island to Oakland, but on account of the great depth of water, a shield driven tunnel was deemed by the engineers to be impracticable.

The California State legislature created the State Toll Bridge Authority in 1929 and in 1931 amended the act, placing responsibility for the execution of the work in the hands of the State Highway Department, assisted by a board of consulting engineers.

Starting:

On July 9, 1933, work was started on this stupendous undertaking with the turning up of the first earth to be excavated with a golden spade, and the touching off of a remote control blast by President Roosevelt. The ceremonies



Photo, Courtesy California Toll Bridge Authority

Figure 83. THE WEST BAY CROSSING—SAN FRANCISCO-OAKLAND BAY BRIDGE
1936

were held on Yerba Buena Island and were attended by the Governors of California and Nevada, past-President Hoover, and many notables of the San Francisco region. Mr. Hoover spoke of this project as "the greatest bridge yet erected by the human race."

General Description:

This bridge consists of two separate and distinct parts, separated by Yerba Buena Island which is pierced by a tunnel. The two sections are also quite different in construction and consequently in appearance; the easterly arm consists of a cantilever span with steel truss approaches, while the westerly arm consists primarily of twin suspension spans. It has the unprecedented length of over eight miles between bridge-heads, or termini, over twice as long as any other existing bridge, and cost about seventy-eight million dollars, also a record for bridge construction. Two decks are provided, the upper carrying six traffic lanes for vehicular traffic and the lower accommodating three trucking lanes and two trolley tracks.

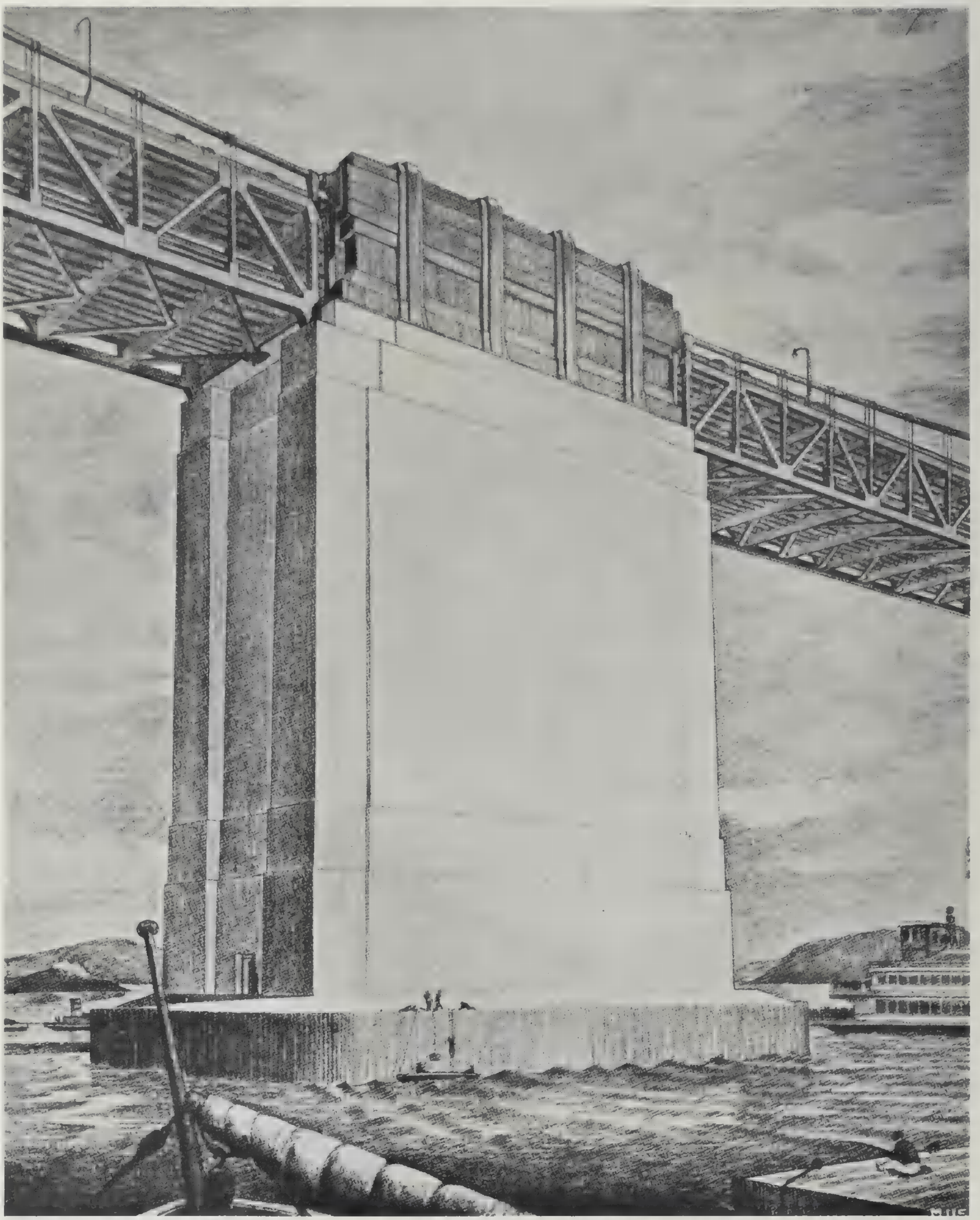
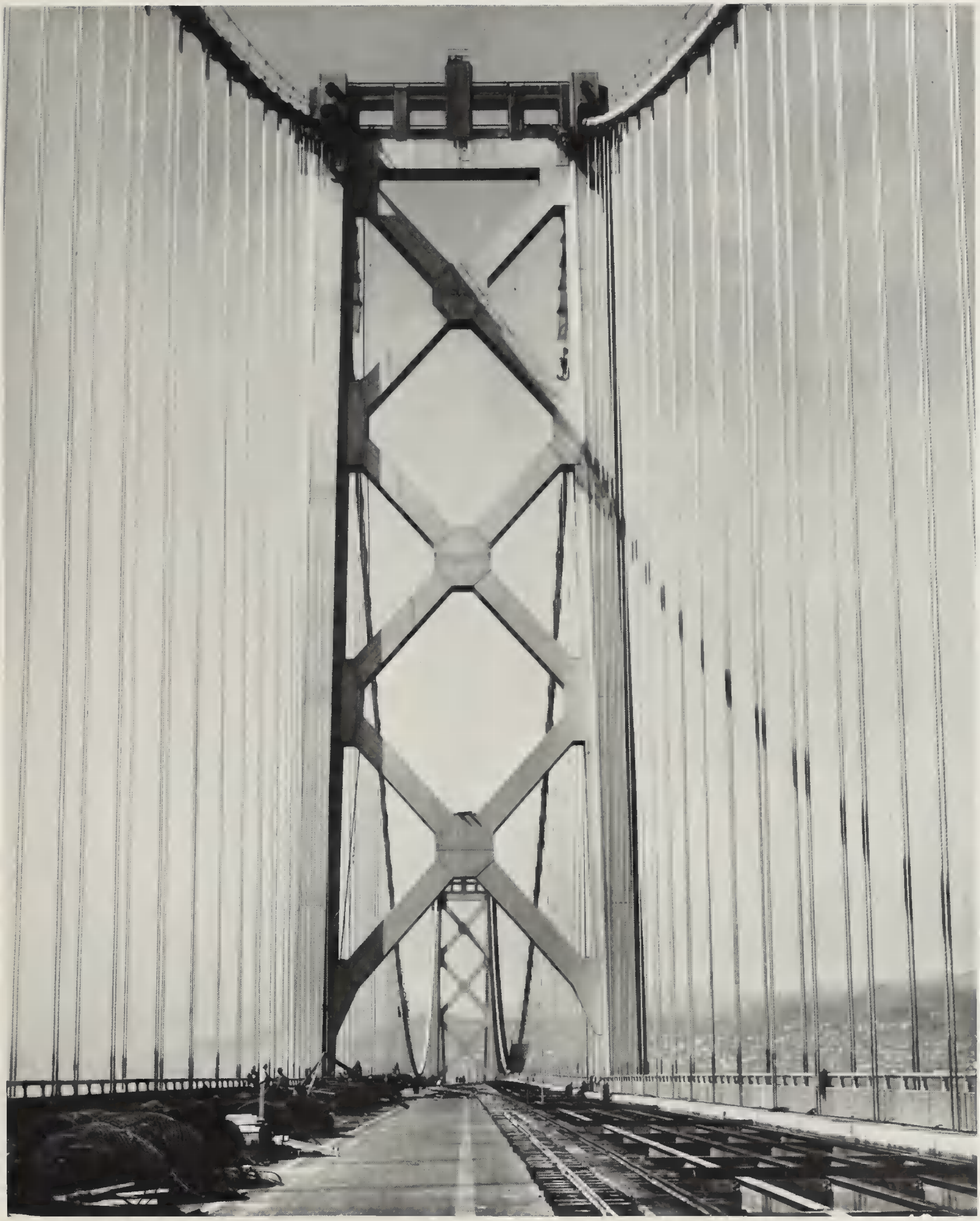


Figure 84. SAN FRANCISCO-OAKLAND BAY BRIDGE
Preliminary Design for Central Anchor Pier



Photo, Courtesy California Toll Bridge Authority

Figure 85. DECK VIEW—SAN FRANCISCO-OAKLAND BAY BRIDGE
1936

Engineering Data:

The unique engineering problems presented by this immense structure are the use of twin suspension spans with their center anchorage pier, the unprecedented depth of foundations, and the placing and sinking of caissons in deep water subject to a tidal current of some 7½ miles per hour. For the suspension spans, rock was found at a maximum depth of 240 feet and for the cantilever span of the east bay crossing, where the rock lay at such a great depth that it could not be reached, the easterly tower pier was sunk to a depth of 242 feet to a clay foundation by open dredging. In general, the sandstone bedrock lies at a maximum depth of about 250 feet under the west bay crossing, overlaid by mud and clay,—the maximum water depth being about 115 feet. At the east bay crossing the formation is clay with sand pockets, the bedrock lying about 300 feet or more below water level.

The twin suspension bridges that span the west bay are, in themselves, among the world's greatest bridges, their suspended spans of 2,310 feet each being exceeded in length only by the George Washington Bridge in New York and by the Golden Gate Bridge, their near neighbor now (1936) nearing completion. It is the only large structure in the world that comprises two suspension bridges placed end to end and necessitating the construction of an anchor pier between them in order to take up the difference in the stresses in the cables between the two spans due to unequal live loads on them.

Similarly, the east bay crossing comprises a cantilever bridge that is also the third largest span of its kind in the world, being exceeded only by the Firth of Forth bridge in Scotland and by the Quebec bridge in Canada. And then the tunnel through Yerba Buena Island 540 feet in length, with a clear width of 65 feet 6 inches and a height of 52 feet 8 inches, is the largest bore in the world. To cap the climax, the foundations for the piers of this bridge have been carried to a greater depth than ever before attained.

The outstanding engineering feature of this bridge, however, is the use of so-called "domed" caissons for the piers of the west bay crossing. This method of controlling the sinking of large caissons in deep water was developed by Daniel Moran, one of the Board of Consulting Engineers, although it had been studied and proposed before, and consists in brief of closing the tops of the dredging chambers with airtight domes. By varying the air pressure in these domes, the control of the sinking process is greatly facilitated. An idea of the magnitude of this structure may be obtained from the dimensions of the central anchorage pier, which is 92 feet by 197 feet in plan, and 500 feet high, 220 feet below water and 280 feet above.

Traffic:

The passenger traffic across San Francisco Bay is very heavy, estimated to consist before the completion of the bridge of 50,000 commuters, in addition to

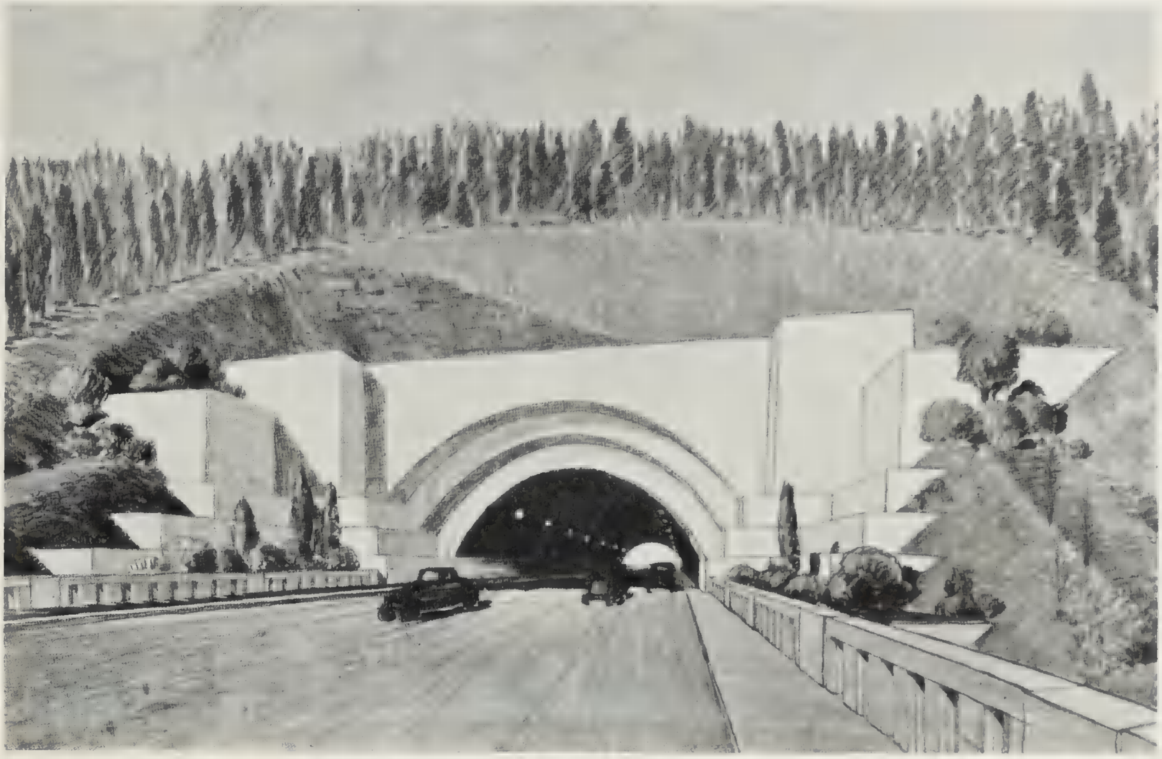


Figure 86. SAN FRANCISCO-OAKLAND BAY BRIDGE
Design for entrance to tunnel on Yerba Buena Island

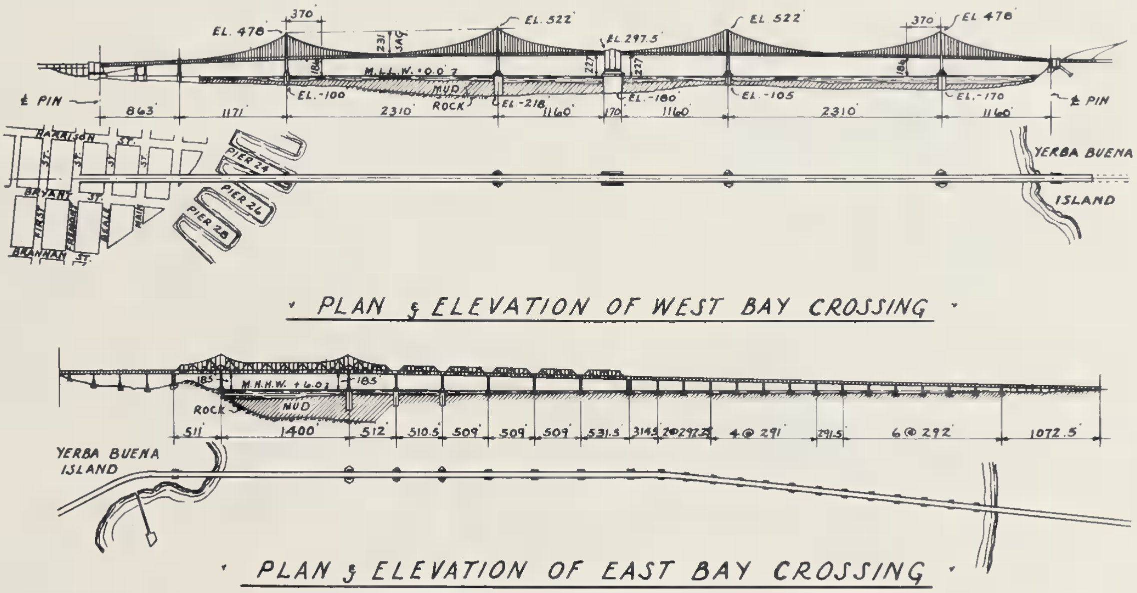


Figure 87A

· SAN FRANCISCO - OAKLAND BAY BRIDGE ·

which the automobile ferries carried 5,000,000 autos with 10,000,000 passengers annually. It is estimated that the bridge in 1937 will carry 8,000,000 autos with 16,000,000 persons and 35,600,000 persons by the interurban electric railway system.

Cost:

The cost is financed by the sale of 4¾ per cent bonds against the revenues, which were purchased by the Government.

Personnel:

The engineering staff is composed of C. H. Purcell, chief engineer; Chas. E. Andrew, bridge engineer, and Glenn B. Wodruff, engineer of design, assisted by a Board of Consulting Engineers consisting of Ralph Modjeski, Moran and Proctor, L. S. Moisseiff, Chas. Derleth, Jr., and H. J. Brunnier. The collaborating architects are Timothy L. Pflueger, Arthur Brown, Jr., and J. J. Donovan.

Architectural features worthy of especial mention are the treatment of the huge center anchorage pier between the two suspension spans, the portals of the tunnel across the island, characterized by deeply recessed concentric arcs, and the tapered design of the suspension bridge towers.

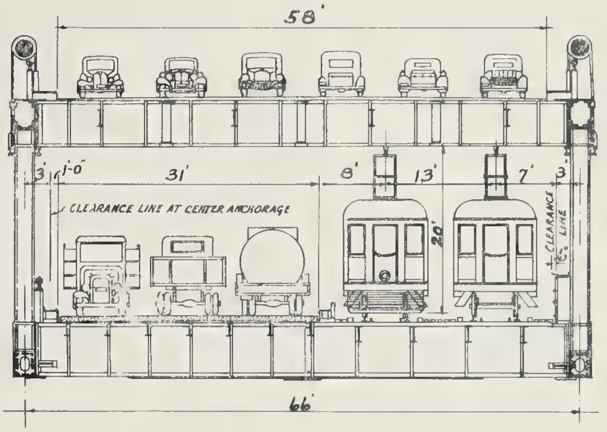
Physical Data:

Length of Main Sections

San Francisco terminal to west anchorage	4,350 feet
West bay crossing	10,300 feet
Yerba Buena Island section	1,800 feet
East bay crossing (steel spans)	11,080 feet
End of steel spans to Oakland terminal	15,970 feet
Total	43,500 feet or 8¼ miles

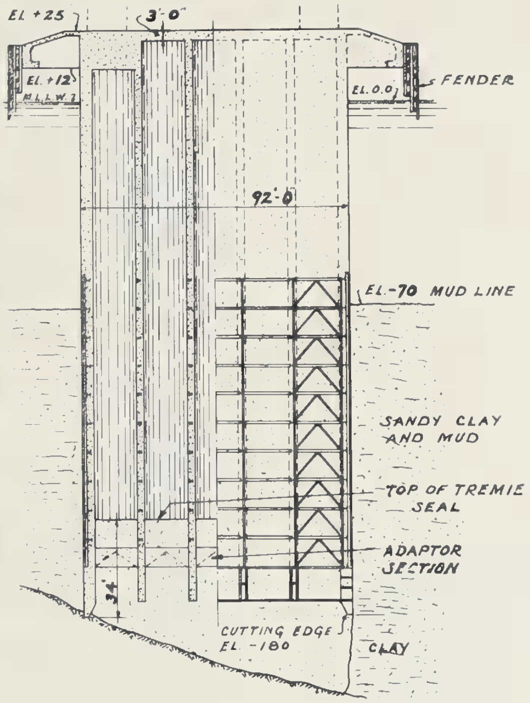
Data on West Bay Suspension Spans

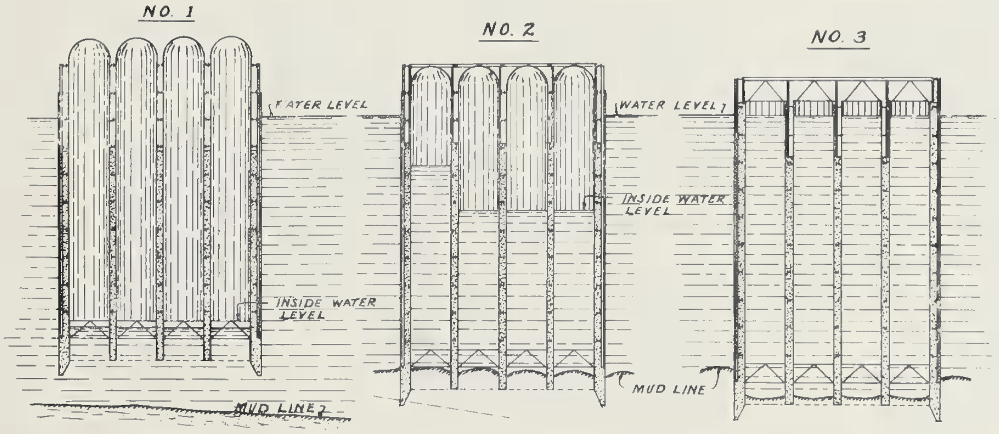
Length of main spans	2,310 feet
Length of side spans	1,160 feet
Dead load of main span (two trusses) approx.	19,100 lbs. per lin. feet
Dead load for side span (two trusses) approx.	20,100 lbs. per lin. feet
Live load approx.	7,000 lbs. per lin. feet
Dead load for utilities, additional, approx.	500 lbs. per lin. feet
Main cables (two)	28¾ inches diameter
Sag of main cables	1/10 span
Diameter of wires	0.195 inch
Wires per strand	472
Strands per cable	37
Towers, above water	474 and 519 feet



·CROSS SECTION·

NO. 4





·SECTIONS SHOWING DOMED CAISSONS AT FOUR STAGES OF SINKING·

·SAN FRANCISCO - OAKLAND BAY BRIDGE·

Figure 87B

Piers, below water	100 to 210 feet
Height of center anchorage, above water	294 feet
Clearance, above water (at center of center span)	200 feet
Clearance, above water (at center anchorage)	216 feet
Data on East Bay Crossing	
Arms of cantilever span (each 412 feet)	824 feet
Suspended span	576 feet
Total	1,400 feet
Anchor arms, each	508 feet
Clearance of cantilever span	185 feet
Through trusses, five spans, each	504 feet
Deck trusses; 14 spans, each	288 feet
Structural Quantities	
Structural steel	148,000 tons
Cable wire	19,100 tons
Reinforcing steel	34,000 tons
Concrete	1,000,000 cubic yards
Timber	30,000,000 feet board measure
Paint	200,000 gallons

SAN FRANCISCO, CALIFORNIA, THE GOLDEN GATE BRIDGE

This is a publicly owned toll bridge, financed by the Golden Gate Bridge and Highway District which consists of San Francisco County south of the bridge and five counties to the north. The cost is estimated at $35,000,000, provided by the sale of district bonds to be retired in forty years. Work was started in 1933 and will be completed in 1937. Although located directly across the entrance to San Francisco harbor no objection to the project was made by the U. S. War Department because it was thought that in case the bridge were ever to be wrecked from any cause, the wreckage would sink to such a depth that it would present no obstruction to navigation.

General Data:

At the site of the bridge, the Golden Gate has a width of about 5,500 feet and a depth of about 300 feet, the bottom being rock with practically no overburden. It was found that a length of span of about 4,200 feet could be obtained by locating the south pier north of the shore line about 1,125 feet in about 65 feet of water. Inasmuch as the tidal range at the site is about 9 feet, the tidal currents nearly 8 miles per hour, and the location subject to rough seas due to the immediate proximity of the Pacific Ocean, the construction of this pier presented a most difficult engineering problem in connection with the project.

The bridge is of the suspension type, comprising a main span of 4,200 feet between towers with balanced side spans of 1,125 feet each. The length over all is 9,217 feet. It carries a 60-foot roadway and two sidewalks 11 feet wide each. The two cables are 36¼ inches in diameter, carried on towers of the fixed-base flexible type 699 feet high from the top of the piers to the center of the cables, or 476 feet high above water. The single roadway is 60 feet wide and the two sidewalks are 10½ feet wide each.

While this bridge holds the world's record for length of span, being 700 feet longer than the George Washington Bridge at New York, the loads which it carries are much lighter; so that, in point of magnitude the New York Bridge is still incomparable. This comparison is evidenced by the size of the cables, the Golden Gate cables being two in number and 36¼ inches in diameter, as against the four cables, 36 inches in diameter, used in the George Washington Bridge.

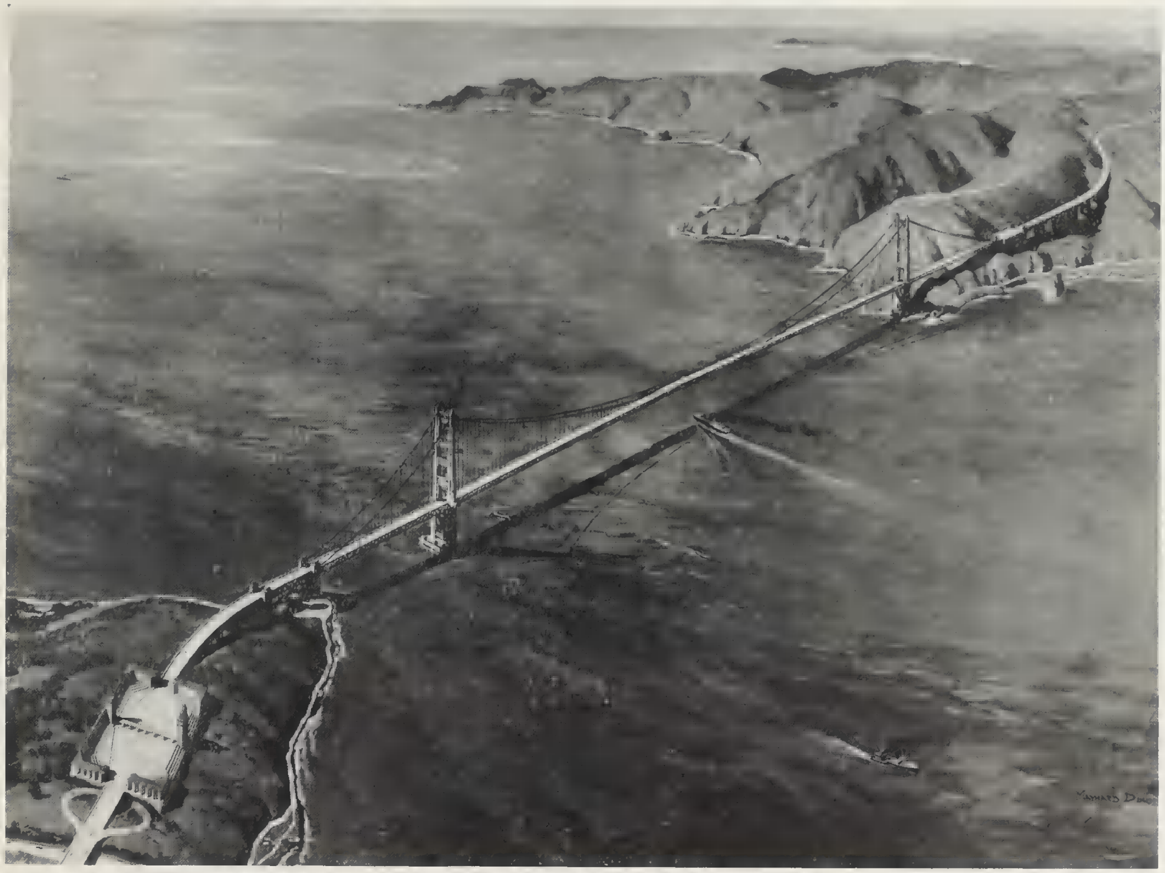
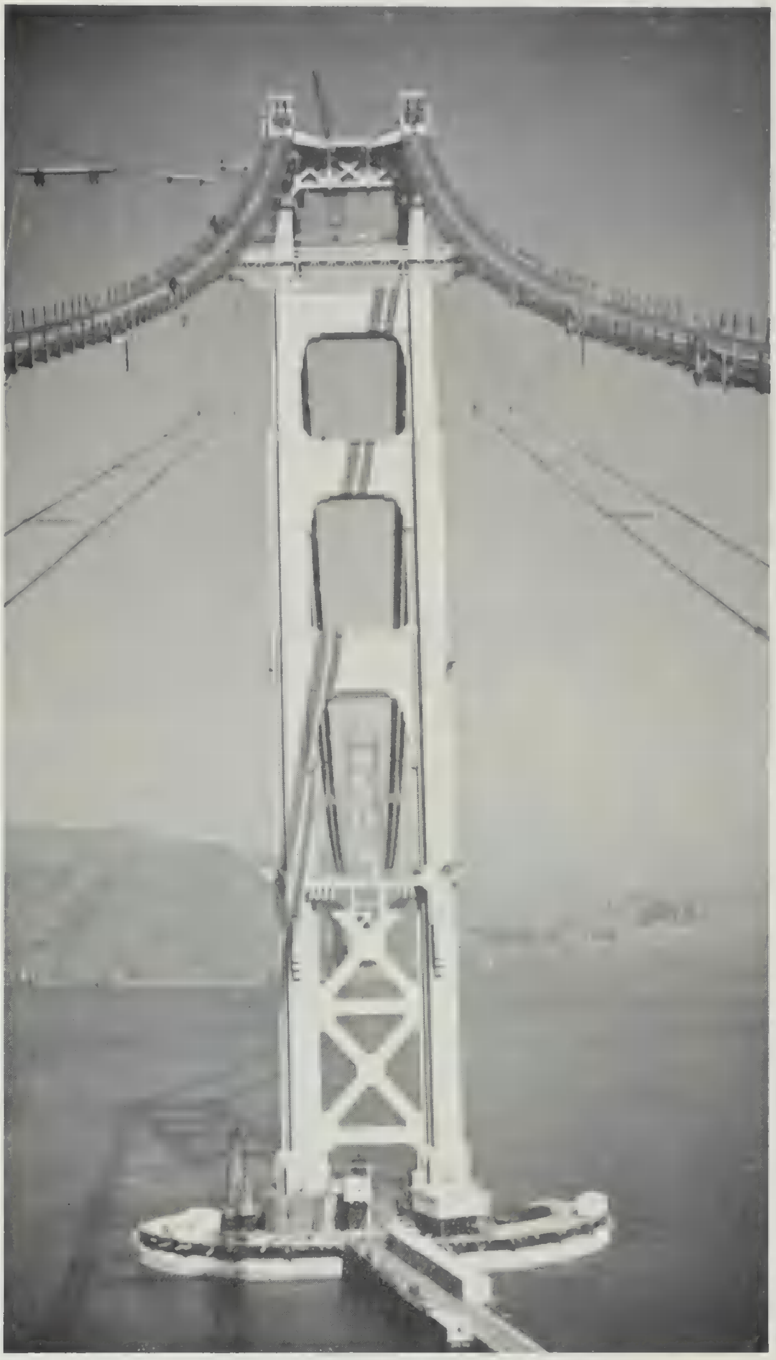


Figure 88. THE GOLDEN GATE BRIDGE, SAN FRANCISCO, CALIFORNIA
J. B. Strauss, Chief Engineer

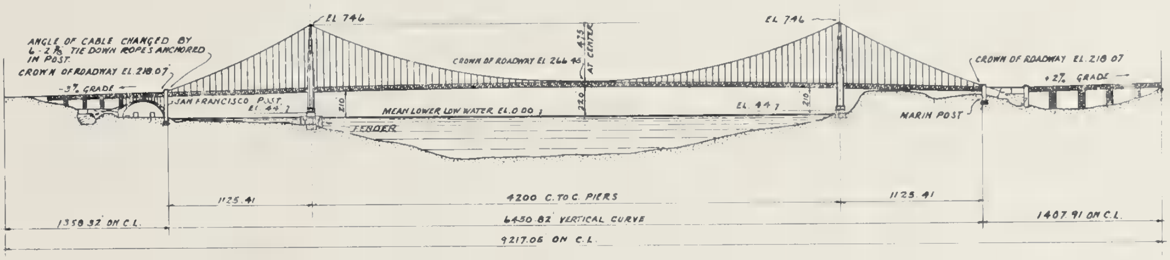


Photo, Courtesy Standard Oil Company of California

Figure 89. CONSTRUCTION VIEW OF TOWER—THE GOLDEN GATE BRIDGE
SAN FRANCISCO, CALIFORNIA—1936
J. B. Strauss, Chief Engineer

Construction of the South Pier:

The difficulties of construction of the south pier have already been enumerated and were met by the construction of a temporary trestle from the south bank out to the pier site, the construction of a concrete cofferdam which forms the permanent fenders protecting the pier, the blasting out of approximately 25 feet of rock in order to obtain a positive anchorage against any possible displacement of the pier by earthquakes, the pouring of about 65 feet depth of underwater concrete, and the construction of the balance of the pier in open cofferdam. These operations differed somewhat from the original plans which contemplated the use of a concrete caisson floated into the enclosure formed by the cofferdam. Before pouring the underwater concrete seal, eight steel tubes, five feet in diameter and flaring out to 15 feet diameter at the base, were set on the rock and the concrete poured around them, the object being to provide means of inspecting the rock surface by applying air to these cylinders and using them as working chambers to correct any defect in the foundation surface. None, however, was found when the inspection was made.



· THE GOLDEN GATE BRIDGE ·
SAN FRANCISCO, CALIFORNIA

Figure 90.

The north pier, founded on rock in shallow water, was also set into the rock some 25 feet for the same reason that applied to the south pier. Another detail, also a precaution against forces due to possible earthquake action, consists in anchoring each leg of each tower into the concrete piers to the quite unusual depth of about fifty feet. The south pier is 90 x 185 feet in size and 144 feet in height to the base of the steel towers. The fender-cofferdam was built in the form of an elliptic enclosure 155 feet by 292 feet in size and 27½ feet thick, consisting of 22 sections poured under water in several stages.

Architecture:

The prominent architectural feature of this bridge is the treatment of the steel towers, seven hundred feet high, of cellular construction, presenting a vertical ribbed surface. These towers diminish in width toward the top by means of offsets at three stages. Above the roadway the two tower legs are connected by four finely proportioned struts, no diagonals being used. The design presents a very pleasing appearance.

Personnel:

The engineering staff consists of J. B. Strauss, Chief Engineer, Clifford E. Paine, Principal Assistant Engineer and Russell G. Cone, Resident Engineer, assisted by a Board of Consultants including O. H. Amman, Leon S. Moisseiff and Chas. Derleth, Jr.

SEATTLE, WASHINGTON, LAKE UNION BRIDGE

This is a cantilever deck-type highway bridge completed in 1932 with a length of 2,956 feet comprising a main span of 800 feet with a clearance over the channel of 135 feet. Six lanes of vehicles are provided for. Dedicated on the 200th anniversary of George Washington's birth, it has been named the George Washington Memorial Bridge. Jacobs and Ober were designing engineers. The volume of traffic over this bridge is exceptionally heavy.

SOUTH AFRICA, BIRCHENOUGH BRIDGE OVER THE SADI RIVER

This is a highway bridge located in Southern Rhodesia and is an overhead type steel arch bridge of 1,080-foot span and 216-foot rise. In appearance it is quite similar to the Kill van Kull bridge at Bayonne, New Jersey. Its principal claims to fame are the facts that it is the third longest bridge of its type in the world, and that a new steel alloy, called "Cromador Steel" was exclusively used in its construction. This steel has an ultimate strength of from 83,000 to 96,000 pounds per square inch and a minimum yield point of 51,500 pounds per square inch. The designer was Mr. Ralph Freeman of Sir Douglas Fox and Partners. It was opened for traffic on December 2, 1935.

SPAIN, RAILROAD BRIDGE OVER THE ESLA RIVER

A bridge over the Esla River in Spain, now boasts the longest concrete arch span in the world—627 feet clear span with a rise of 205 feet, carrying the double track line of the Zamora-Orense-La Coruna Ry. Like most of these European long-span concrete bridges, the arch rib (a single one in this case) is hollow and is composed of three chambers, the vertical walls of which are 2.3 feet thick, while the extrados and intrados walls are from 2.95 to 4.35 feet thick. The arch ring is 25.9 feet wide by 12.1 feet deep at the crown and 29.7 feet by 19.7 feet at the spring. As is also the case with recent European bridges, the working unit stress employed is high, as compared with American practice, in this case amounting to 1,223 pounds per square inch in compression.

STATEN ISLAND, NEW YORK, THE GOETHALS BRIDGE AND THE OUTERBRIDGE OVER THE ARTHUR KILL

Named after General Goethals, the builder of the Panama Canal, this bridge connects Staten Island with Elizabeth, New Jersey. It is of the cantilever type with a main span of 672 feet and a total length of 8,600 feet and provides for four lanes of vehicles and two walks. The Outerbridge Crossing of the Arthur Kill connects Staten Island with Perth Amboy, New Jersey, and was named in honor of E. H. Outerbridge, late chairman of The Port of New York Authority. Completed in 1928, it is similar to the Goethals bridge, but with a total length of 10,200 feet and a main span of 750 feet. Both of these bridges were designed by Waddell and Hardesty, Engineers.

STOCKHOLM, SWEDEN, TRANBERG SOUND BRIDGE

The notable feature of this bridge is its main span, a concrete arch 593.5 feet in length center to center of supports, or a clear span of 585 feet, one of the longest in the world, with a rise of 88½ feet. Its total length is 1,900 feet and it carries a 39-foot roadway, two 8-foot walks (the Swedes still walk), two 4 foot bicycle tracks (the Swedes also still pedal), and two electric railway tracks (not yet displaced by the automobile). The main arch is of the two ribbed type, each rib having a width of 29.5 feet, a depth of 16.4 feet at the abutments and 9.8 feet at the crown, and is designed as a hollow box of three compartments or cells. The slab thicknesses at the crown are 18 inches for the top and 19½ inches for the bottom. The side walls are 19½ inches thick and the vertical division walls 16 inches thick. In each rib there are 108 round bars ⅞ inches in diameter. The deck is carried on cross-walls hinged at the base to allow motion due to expansion and contraction, an unusual feature. A concrete mixture of one part cement to two and six-tenths fine aggregate and two and five-tenths coarse aggregate was used, giving a 28 day strength of 6,100 pounds per square inch and the working stress assumed was 1,400 pounds per square inch. About 28,500 cubic yards of concrete, 1,300 tons of reinforcing steel and 1,300 tons of structural steel were used in this bridge, completed at a cost of about $5,300,000. The foundations are on rock close to the surface. The engineer in charge was Major Ernst Nillson, Chief Engineer of bridge construction for the Stockholm Harbour Board.

SUISUN BAY, CALIFORNIA, SOUTHERN PACIFIC RAILWAY BRIDGE

Since 1879 the Southern Pacific Railroad has maintained a ferry for carrying its trains across Suisun Bay, in California. Because of the great expense involved the bridging of the bay was not undertaken until 1929. At the bridge site the water is about 55 feet deep and mud is an additional 35 feet in depth, while the rock lies at a maximum depth of 143 feet below low water, the overlying material being sand or clay and firm gravel.

The principal characteristics of the bridge are:

Length between abutments, 5603.5 feet
Clearance above mean high water, 70 feet for fixed spans and 135 feet for the lift span
Through trusses, 5 at 531 feet, 2 at 529½ feet in length
Deck trusses, 1 at 506½ feet and 1 at 266½ feet in length
Lift span 336 feet center to center of piers

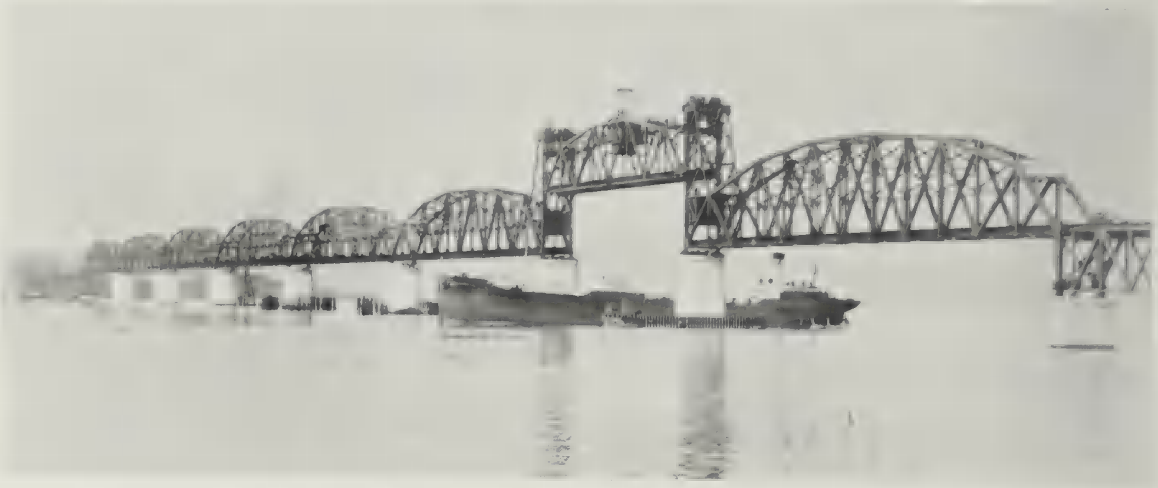


Figure 91. RAILROAD BRIDGE OVER SUISON BAY, MARTINEZ, CALIFORNIA 1931

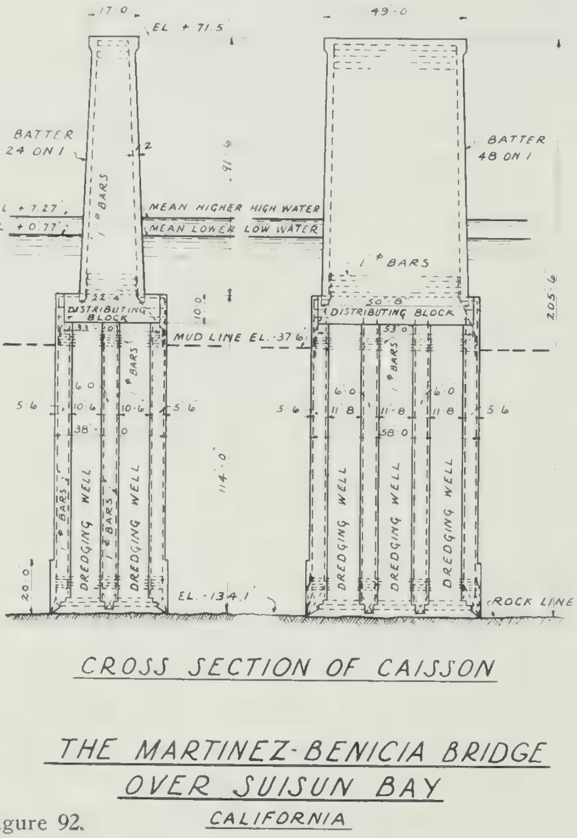


Figure 92.

Eight of the piers were constructed by what is known as "the sand island method", the first instance of the use of this method which was later used at the Huey P. Long Bridge at New Orleans. Provision for earthquake shocks was one reason for carrying the piers of this bridge to the rock, two geologic faults occurring in the vicinity, and for this reason also the pier bases and shafts were heavily reinforced. The sand island method consisted, essentially, in sinking a steel cylinder 81 feet in diameter, from a temporary octagonal pile dock built around the pier site and, when it camee to rest, in dredging out the mud from the inside of the cylinder and filling with sand nearly to the top. On the artificial sand island thus formed a steel cutting edge was laid and forms erected for the construction of a reinforced concrete caisson containing six dredging wells. Sand was then dredged from out the wells, and the caisson sunk by its own weight. When the rock was reached, the wells were sealed with about 30 feet of underwater concrete, the water was pumped out, and the pier shaft completed in the dry.

Personnel:

Moran and Proctor were consulting engineers for the foundation work, Waddell and Hardesty for the lift span and towers, Ralph Modjeski for preliminary studies. All work was executed under the direct supervision of C. R. Harding, Assistant to the President, Southern Pacific Railroad, and W. H. Kirkbride, Engineer Maintenance-of-way, with the assistance of G. W. Rear, Engineer of Bridges.

SYDNEY, NEW SOUTH WALES, BRIDGE OVER SYDNEY HARBOR

Description:

Justly classed as one of the world's outstanding bridges is this span crossing Sydney Harbor, New South Wales, Australia, opened for traffic in March 1932. This bridge is of the half-through or overhead type of double ribbed steel arches, springing between massive masonry pylons with a span of 1,650 feet.

Physical Data:

Length of steel structure, 3,770 feet
Length of main span, 1,650 feet
Width of roadway, 57 feet
Four electric railway tracks
Two sidewalks, 10 feet wide
Maximum height of steelwork, 437½ feet
Vertical clearance (Max.), 172½ feet
Pylons—concrete, granite faced
Weight of steel, 50,288 tons

Architecture:

Outside of the graceful lines of the parabolic arch itself, reminiscent of Lindenthal's Hell Gate Arch, the principal esthetic interest centers in the treatment of the massive pylons at the ends of the arches, which attain a height of 285 feet above the water and are constructed of concrete with granite facing. They stand out from the steel framework of the arch, giving the effect of somewhat independent structures. It is interesting to note that when the architects, Sir John Burnet and Partners, a London firm of recognized eminence, were consulted as to the appearance of the bridge from a purely esthetic standpoint, they advised no modification of the form of the arches dictated by the structural requirements. The pylons do not perform a necessary structural function, but are intended to convey to the mind the impression of mass stabilizing the steel structure on its true bearings at the springing lines of the arch.

Engineering Features:

While this arch is a few feet shorter than the Kill van Kull arch in span, the loads to be carried are far greater, which entitles it to be classed as the greatest steel arch yet built. The foundation conditions were not difficult, the rock lying only about 30 feet below the surface. The erection methods used were unique in that the superstructure was erected as a cantilever held by backstays of temporary cables, 156 cables, 2¾ inches diameter being required at each end. These cables were anchored in the solid rock. One naturally wonders why, with solid rock so near the surface, a suspension bridge would not have proved more economical for this project than the arch selected, but alternate general plans and bids indicated otherwise. Perhaps the answer is partly to be found in the reported admission of the constructing firm that it lost more than a million dollars on its contract, a loss attributed, however, to excess cost due to labor difficulties.

An idea of the magnitude of this bridge may be obtained from the fact that the thrust of the arch ribs against the skew-backs is about 22,000 tons each.

The bridge was designed by Mr. Ralph Freeman, of Sir Douglas Fox and Partners, assisted by the architects, Sir John Burnet and Partners, both of London.

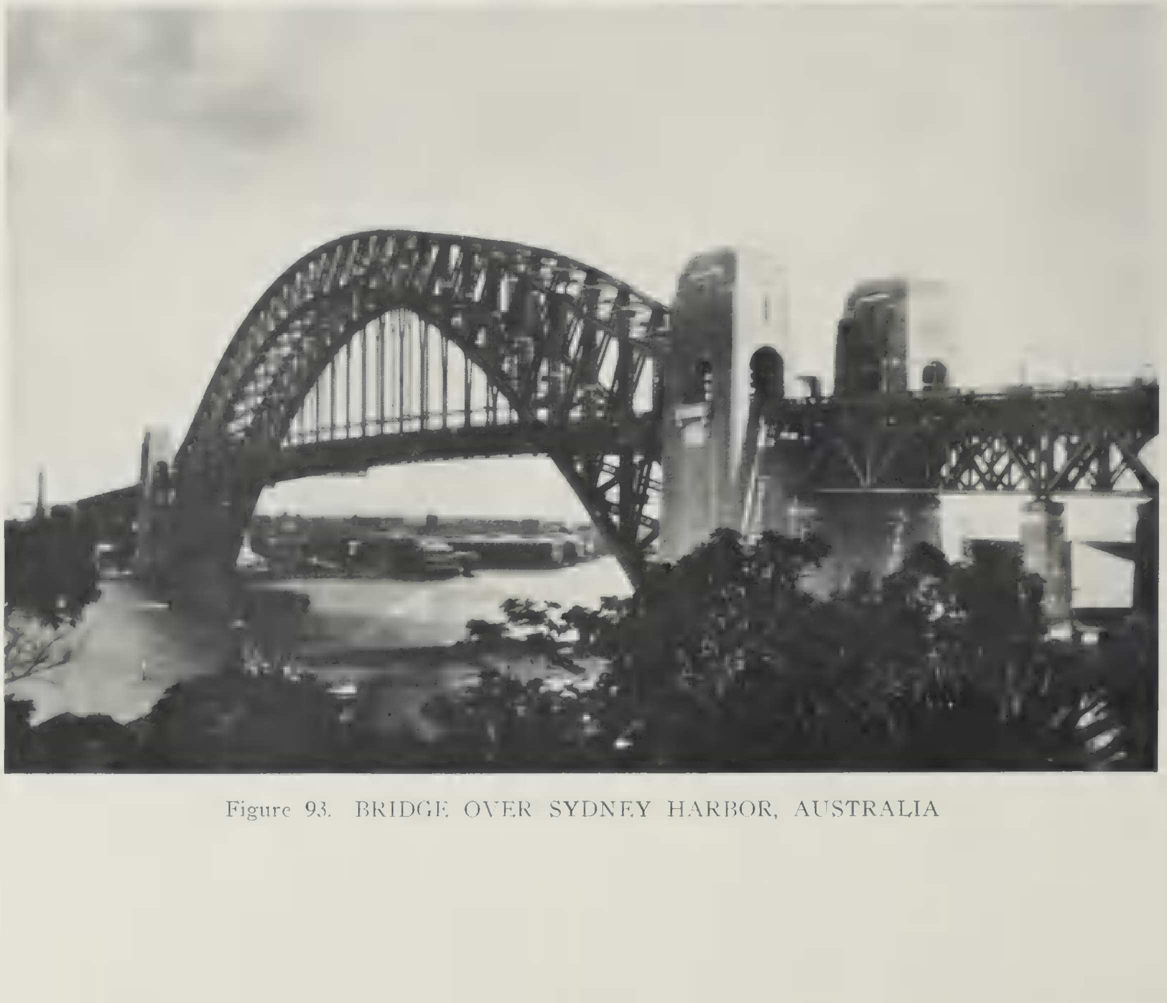
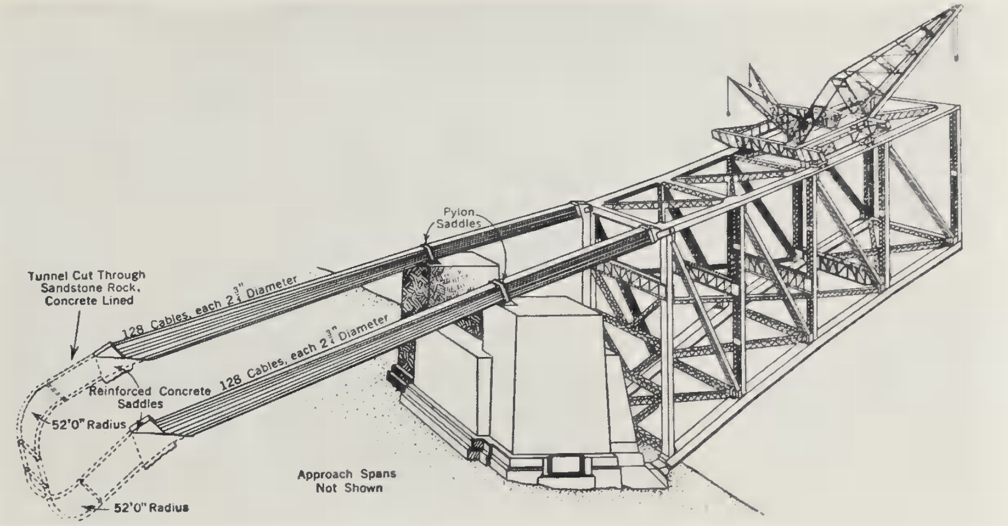
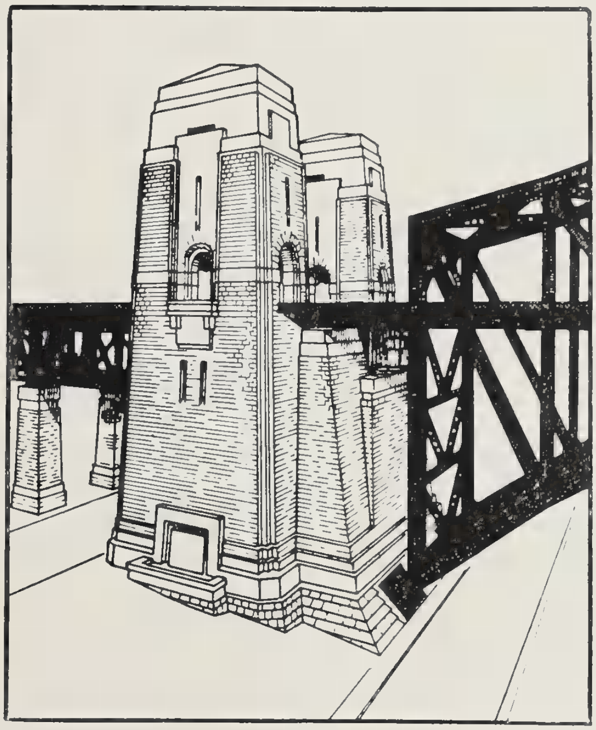


Figure 93. BRIDGE OVER SYDNEY HARBOR, AUSTRALIA


Pylon Saddles
Tunnel Cut Through Sandstone Rock, Concrete Lined
128 Cables, each 2¾" Diameter
128 Cables, each 2¾" Diameter
Reinforced Concrete Saddles
52'0" Radius
52'0" Radius
Approach Spans Not Shown



Figures 94A, 94B
APPROACH SPANS AND PIERS,
BRIDGE OVER SYDNEY HARBOR,
AUSTRALIA

SYRACUSE, NEW YORK, GRADE CROSSING ELIMINATION

The most impressive achievement of the past decade in the elimination of railroad grade crossings is undoubtedly that completed at Syracuse, New York, where for almost a century the main line of the New York Central Railroad has occupied one of the main streets of the city, cutting through the heart of its business district. The problem involved the construction of an elevated structure through the city, mostly for three tracks, and requiring the construction of thirty-one bridges, many over important streets. On this account, considerable study was given to making these structures attractive in appearance. In general, the bridges are of the through plate-girder type, the steel girders decorated by thin plates covering the exposed edges of the girder flanges. In some of the structures these plates give a curved line, or soffit, to the girders. The abutments are of concrete, with pilasters carried above the tops of the girders at the abutments of the more important structures. In addition to the bridges a million and a half cubic yards of fill, extensive retaining walls, and a new passenger station, were involved in the project. In the construction of the heavier plate girder bridges, nickel steel was used in order to keep the sections as small as possible.

The work was planned and carried out by the engineering department of the New York Central Railroad, J. W. Pfau, Chief Engineer, H. T. Welty, Engineer of Structures.

TOLEDO, OHIO, HIGHWAY SUSPENSION BRIDGE ACROSS THE MAUMEE RIVER

Built in 1930. A typical suspension bridge comprising a 785-foot main span and 233½ foot side spans, a 54-foot roadway and two 6-foot walks. The roadway pavement is a concrete slab designed for future asphalt surfacing. Foundations are on bed-rock at a depth of about 60 feet. This bridge has been named the Anthony Wayne Bridge in honor of "Mad Anthony Wayne" who commanded the American troops at the Battle of Fallen Timbers which took place about ten miles up the river.

Waddell and Hardesty were designing engineers, with Leon Moisseff as consulting engineer and Cass Gilbert as consulting architect.

VANCOUVER, CANADA, BURRARD STREET BRIDGE

A monumental structure opened for traffic July 1st, 1932, and costing about three million dollars, this bridge 2,900 feet long carries a 60-foot roadway and two 9-foot walks on an upper deck, with provision for a future lower deck. It is characterized by massive masonry portals at each end of the 315-foot center span. J. R. Grant was consulting engineer.

VICKSBURG, MISS., A PRIVATELY OWNED TOLL BRIDGE

A privately owned toll bridge over the Mississippi River, built in 1930. The main structure is of the cantilever type, with a center span of 825 feet, 2 inches, and anchor arms 420 feet, 8⅜ inches and 418 feet 11⅞, carrying an 18 foot highway and a single track railway. Its length over all steel is 7,484 feet, 7 5/16 inches. The four river piers were founded at a depth of 110 feet below average low water by pneumatic caissons of steel surmounted by open cofferdams of timber. The designers were Harrington, Howard and Ash.

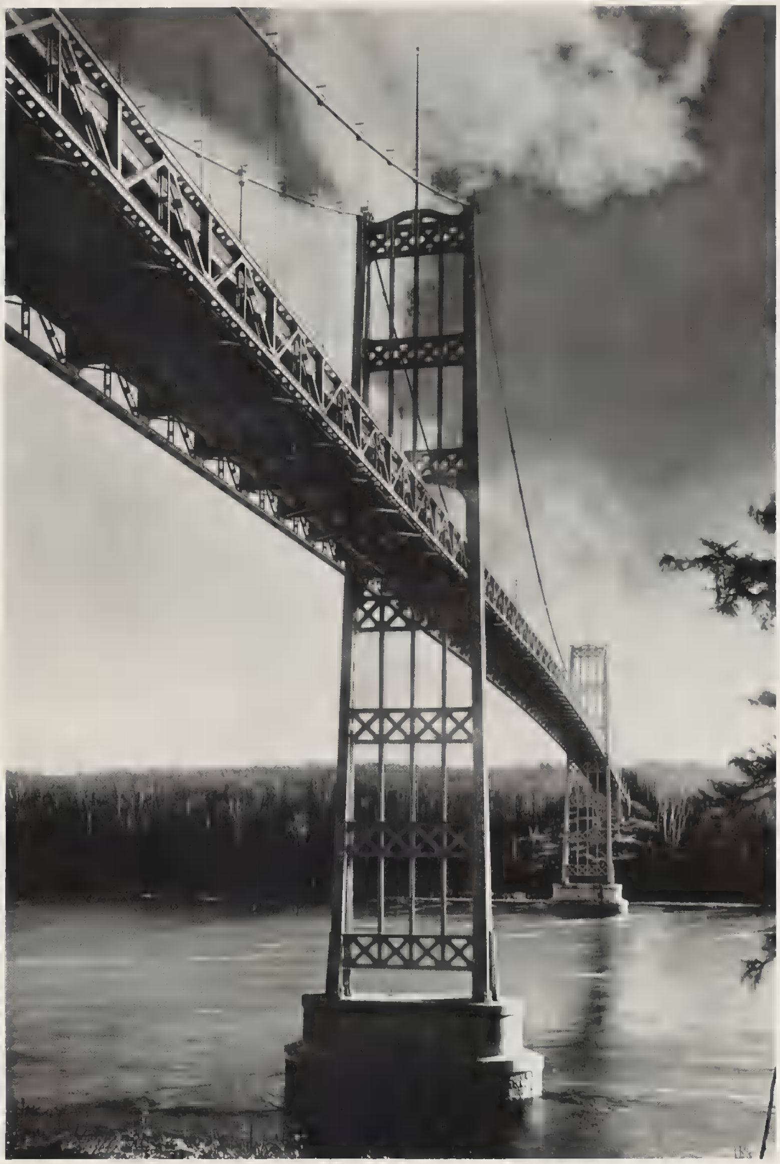


Figure 95. WALDO-HANCOCK BRIDGE OVER THE PENOBSCOT RIVER, BUCKSPORT, MAINE—1931
Robinson & Steinman, Engineers

VINCENNES, INDIANA, MEMORIAL BRIDGE

Named the General George Rogers Clark Memorial Bridge in honor of the famous explorer of that name, a handsome reinforced concrete bridge has been constructed across the Wabash River at historic Vincennes. It consists of seven reinforced concrete arches of the open spandrel type, the longest having a span of 180 feet.

At one end there is a large plaza and a memorial building located at the site of old Fort Sodsville, designed by Bennett, Parsons and Frost, architects, of Chicago.

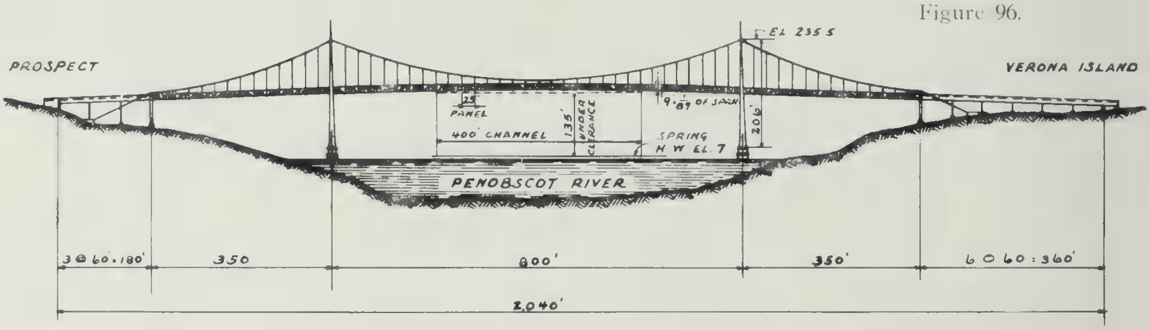
WALDO-HANCOCK BRIDGE, MAINE

This is an excellent example of a modern suspension bridge of economical design for highway purposes. The main span is 800 feet long between tower centers, and the side spans are 350 feet long. A touch of modern architecture is to be seen in the omission of diagonal bracing in the towers and the use of rigid laced struts to replace them with apparently useless vertical members placed between the struts. (See the Mid-Hudson Bridge at Poughkeepsie for comparison.) This bridge was awarded first prize in its class for the year 1931 by the Jury of Awards of the American Institute of Steel Construction.

WASHINGTON, D. C., ARLINGTON MEMORIAL BRIDGE

The project for the construction of a Memorial Bridge across the Potomac from Washington to the Arlington National Cemetery was first suggested by President Andrew Jackson over seventy-five years before its actual start. The first active steps in carrying out the project were taken in 1913 with the appointment of a commission to procure a suitable design, the duties of which were not carried out until some nine years later because of delay in the appropriation of funds for the purpose. The location is a commanding one, connecting the Lincoln Memorial with the Lee Mansion at Arlington and carrying the Mall treatment of Washington and L'Enfant's City Plan across the Potomac. The designing engineer selected was Mr. John L. Nagle, of the Corps of Engineers, U. S. A. and the architects appointed were Messrs. McKim, Meade and White of New York. The work was executed under the direction of Col. C. O. Sherrill, Chief Engineer (later succeeded by Lt. Col. U. S. Grant, 3rd) and W. J. Douglas, Consulting Engineer, with J. B. Strauss as engineer for the draw span.

Figure 96.



• ELEVATION • OF • WALDO - HANCOCK • SUSPENSION • BRIDGE •

BUCKSPORT, MAINE

The bridge as constructed comprises eight reinforced concrete arch spans and a center bascule span of steel, so designed as to harmonize with the masonry spans in appearance and in fact scarcely distinguishable therefrom. The concrete spans and piers are faced with gray Mt. Airy granite, and the exposed steel work of the draw span is painted a similar color. The architecture is severely simple:—its beauty depends upon the perfection of its general proportions and of its adornment with sculptured pieces in the spandrels over the piers depicting an eagle with spread wings and flanked by fasces, and the conventionalized buffalo heads on the keystones. At the Arlington end of the bridge are massive square pylons surmounted by conventionalized eagles. The

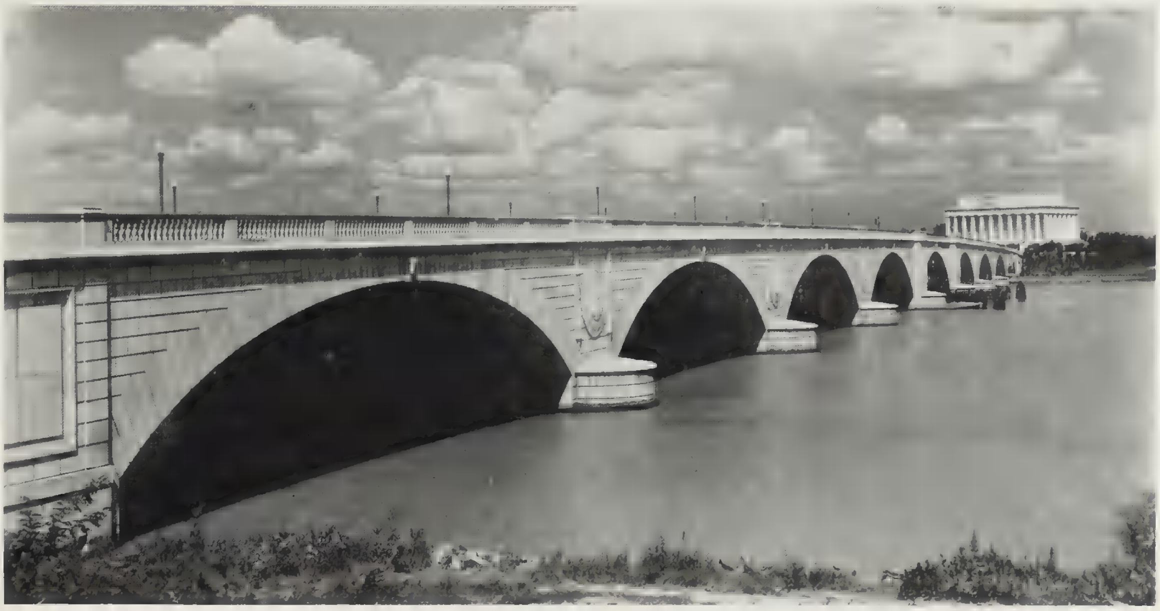


Figure 97. GENERAL VIEW—THE ARLINGTON MEMORIAL BRIDGE, WASHINGTON, D. C.

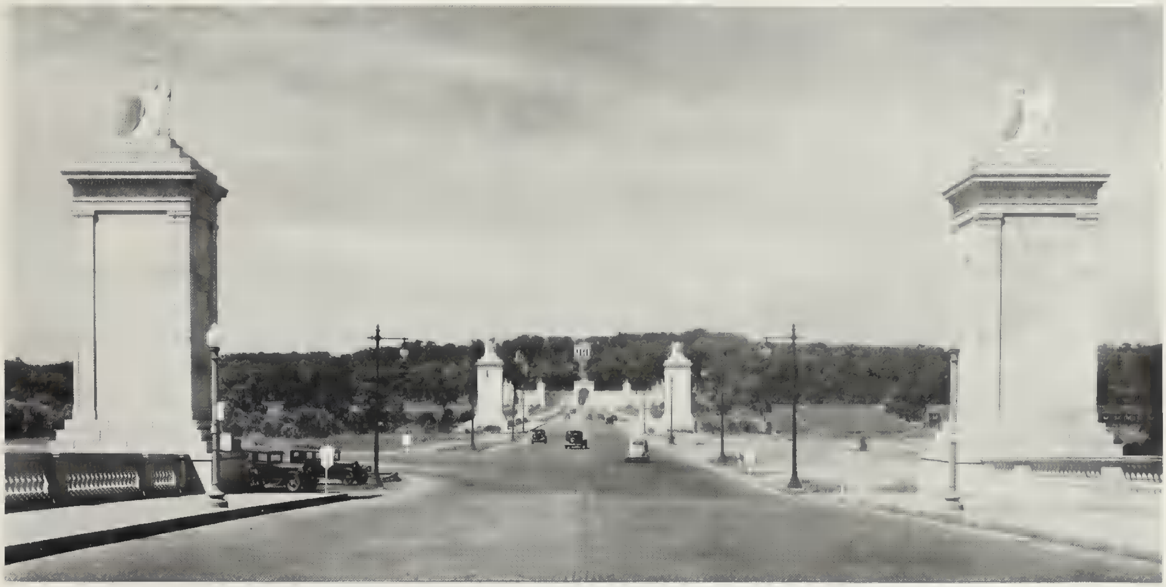


Figure 98. PYLONS—THE ARLINGTON MEMORIAL BRIDGE, WASHINGTON, D. C.

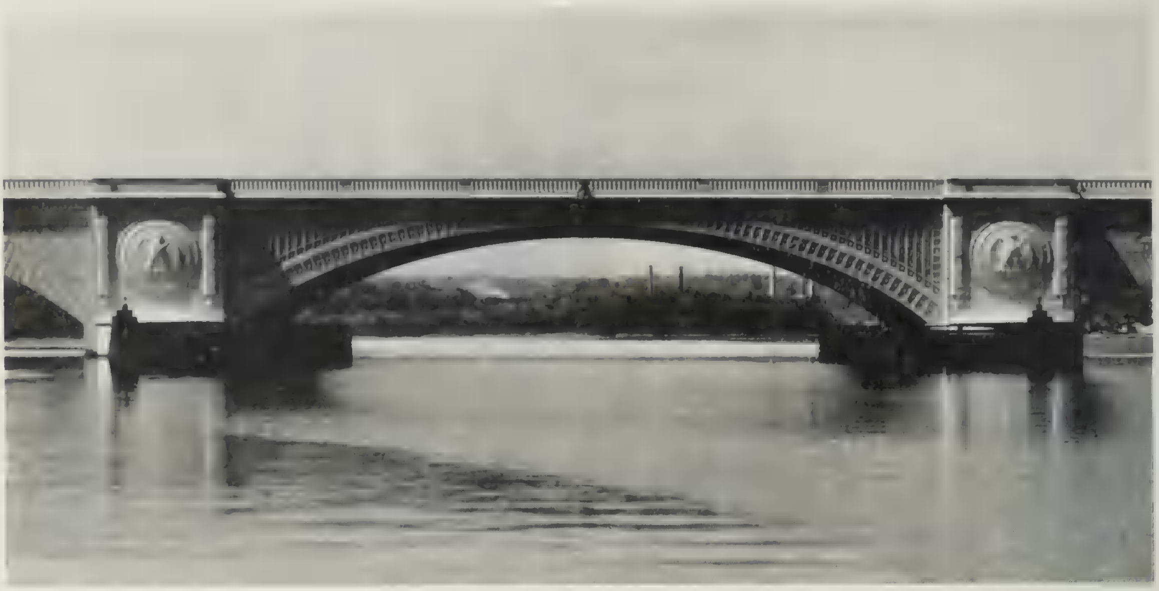


Figure 99. DETAIL OF BASCULE SPAN
THE ARLINGTON MEMORIAL BRIDGE, WASHINGTON, D. C.

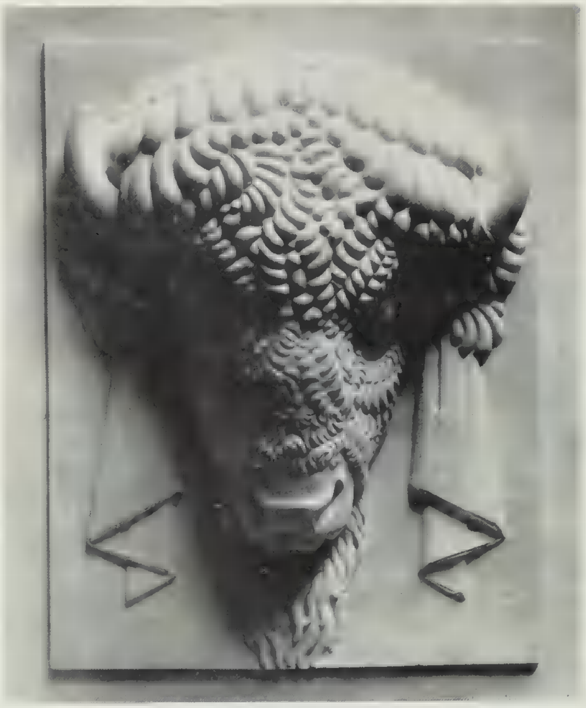


Figure 100.
BUFFALO HEAD—6 FEET HIGH
ARLINGTON MEMORIAL BRIDGE
C. Paul Jennewein, Sculptor

railing or parapet of the draw span is built up of cast aluminum to harmonize with the gray granite of the concrete spans. The length of span is 216 feet for the bascule, and 180 to 166 feet for the concrete spans, the roadway width is 60 feet and the two sidewalks are 14 feet wide. The bascule span is one of the heaviest ever built:—each leaf weighs about 3,800 tons, including the counterweight, which consists of 4,787 tons of concrete, using Swedish iron ore as aggregate in order to obtain the specified weight of 265 pounds per cubic foot. The concrete arches are of the barrel type, with hollow spandrels, and the foundations are carried to rock at about 40 feet below the water level by means of open cofferdams. This monumental structure was opened for traffic on February 21st, 1932, and cost about seven and one-half million dollars.

WASHINGTON, DISTRICT OF COLUMBIA,
CALVERT STREET BRIDGE OVER ROCK CREEK PARK

This is a strikingly beautiful structure, 751 feet long and 125 feet high, comprising three arch spans of 146 feet clear opening and carrying a 60-foot roadway and two 12-foot walks. Provision is made for two street railway tracks on the roadway.

The arches are composed of four concrete ribs, 6 feet wide, which support steel columns, girders and beams, all encased in concrete. Limestone facing is used for all arches and abutments and for filling in the spandrels in order to obtain the appearance of a solid filled arch, which requirement also prompted the use of precast concrete slabs to close the spaces between the soffits of the concrete ribs. The horizontal joints of the stone facing are carried continuously across the entire length of the bridge.

The railings are also of limestone on the abutments and wrought ornamental-iron and stone over the arches. The curbs are of granite and the wearing surface of the roadway is asphalt.

The bridge was built under the direction of H. C. Whitehurst, Director of Highways for the District of Columbia, and C. R. Whyte, Engineer of Bridges. The design is by Modjeski, Masters & Case, Consulting Engineers, ably assisted by Paul P. Crét, Architect.

WESTCHESTER COUNTY, NEW YORK

As Mr. Gilmore C. Clarke, Landscape Architect for the Westchester County Park Commission has written "Bridge design may be considered both an art and a science"—The many beautiful bridges built by the Commission, and designed by its engineering and architectural staff working in collaboration illustrate well the truth of his saying. These bridges range in size from the Croton Lake Arch Bridge with its span of 750 feet, to small stone bridges over creeks and to timber foot bridges. Most of the bridges used to separate highway grade

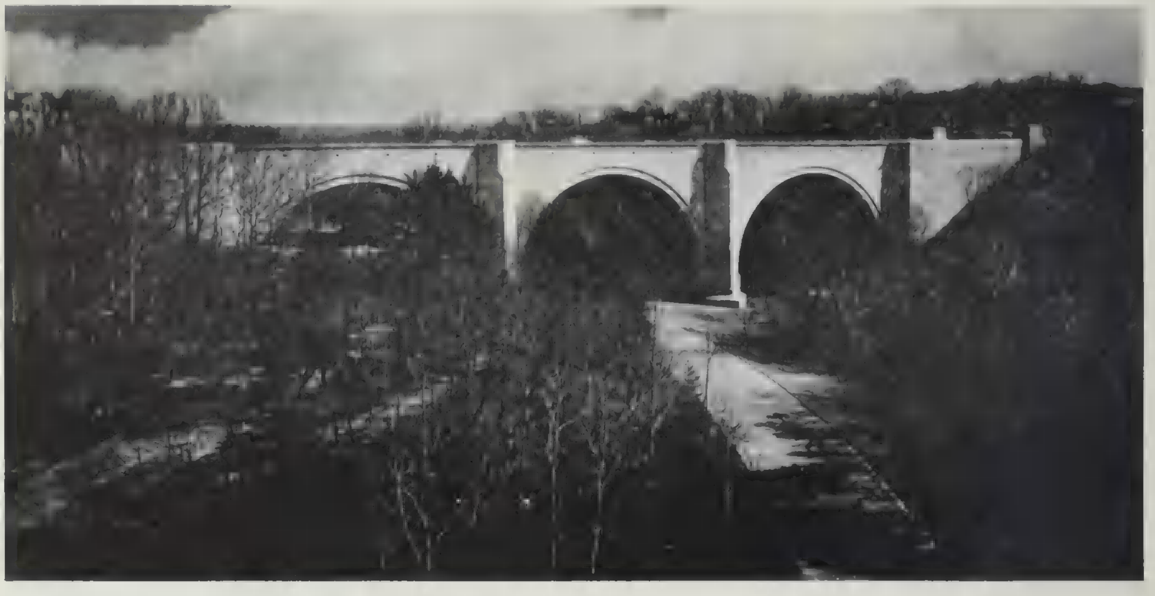


Figure 101.

CALVERT STREET BRIDGE,
WASHINGTON, D. C.

Modjeski Master & Case, Engineers
Paul P. Crét, Architect
1936

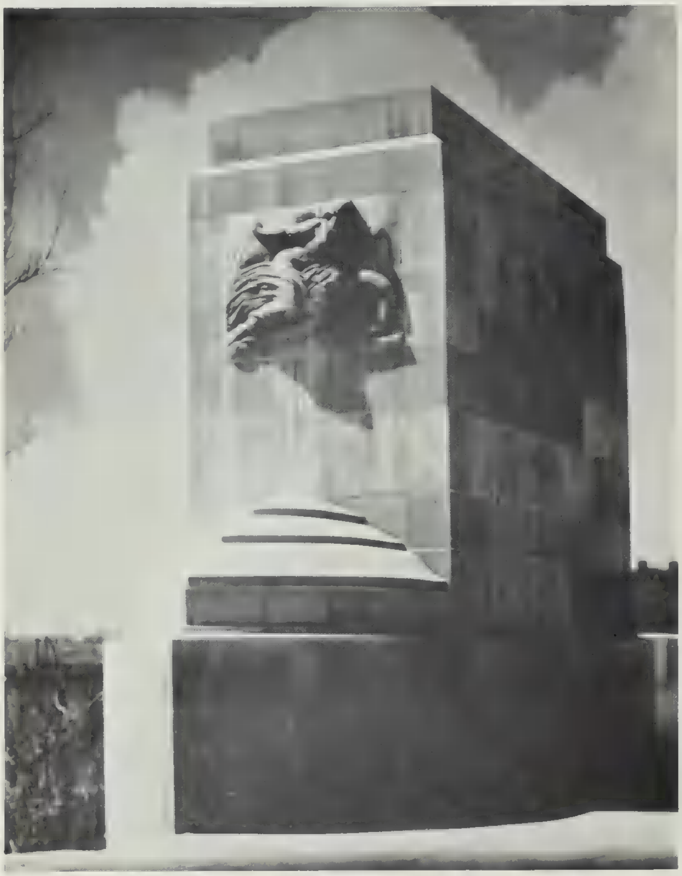


Figure 102. DETAIL

CALVERT STREET BRIDGE
WASHINGTON, D. C.

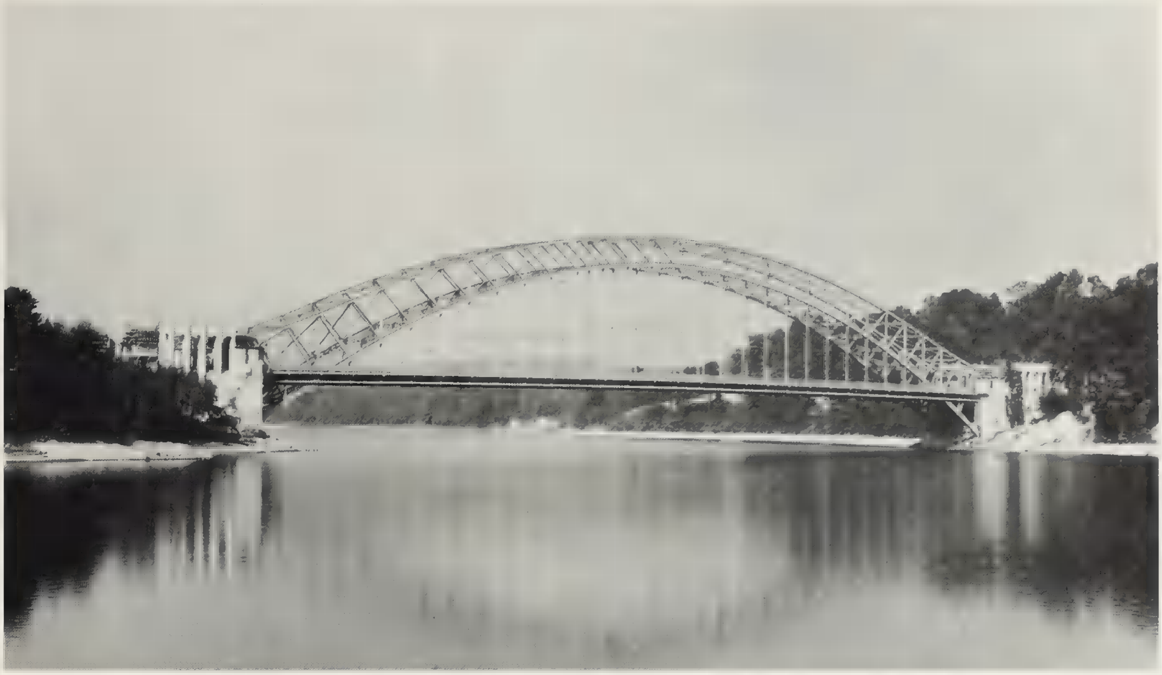


Figure 103. CROTON LAKE ARCH BRIDGE, WESTCHESTER COUNTY, NEW YORK

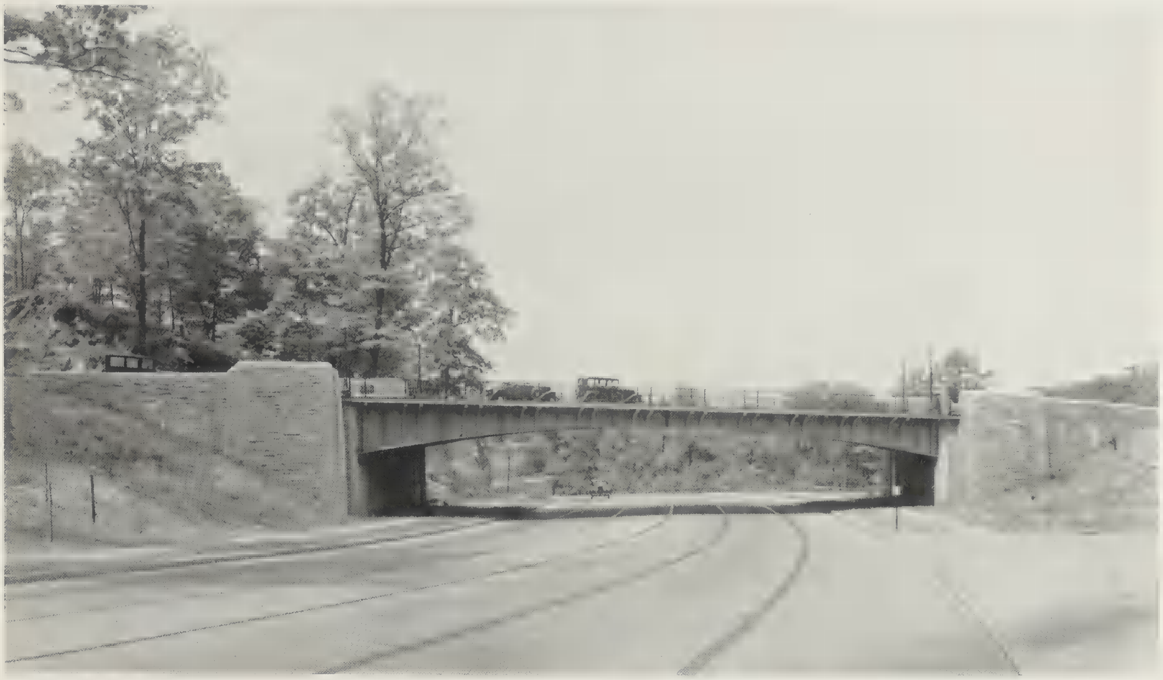


Figure 104. PARKWAY BRIDGE, WESTCHESTER COUNTY, NEW YORK

crossings are concrete arches faced with stone, and designed as rigid frames. One of the most interesting bridges is a reinforced concrete structure on a curve, the roadway supported on concrete brackets radiating from a single line of circular piers located on the center line of the bridge.

These Westchester County Bridges have been built under the direction of Jay Downer, Chief Engineer, Leslie G. Holleran, Deputy Chief Engineer, and A. G. Hayden, Designing Engineer, assisted by such eminent Architects as Delano and Aldrich, Bowden & Webster, Gilmore D. Clarke and Chas. W. Stoughton.

The Croton Lake Bridge illustrated was designed by Howard Baird, Engineer, and C. F. Loyd of the Westchester County Park Commission.

Another New York State Park Commission that has recently built some fine bridges is that for Long Island, of which Arthur E. Howland is Chief Engineer. The work done by both of these Commissions is adjacent to New York City.

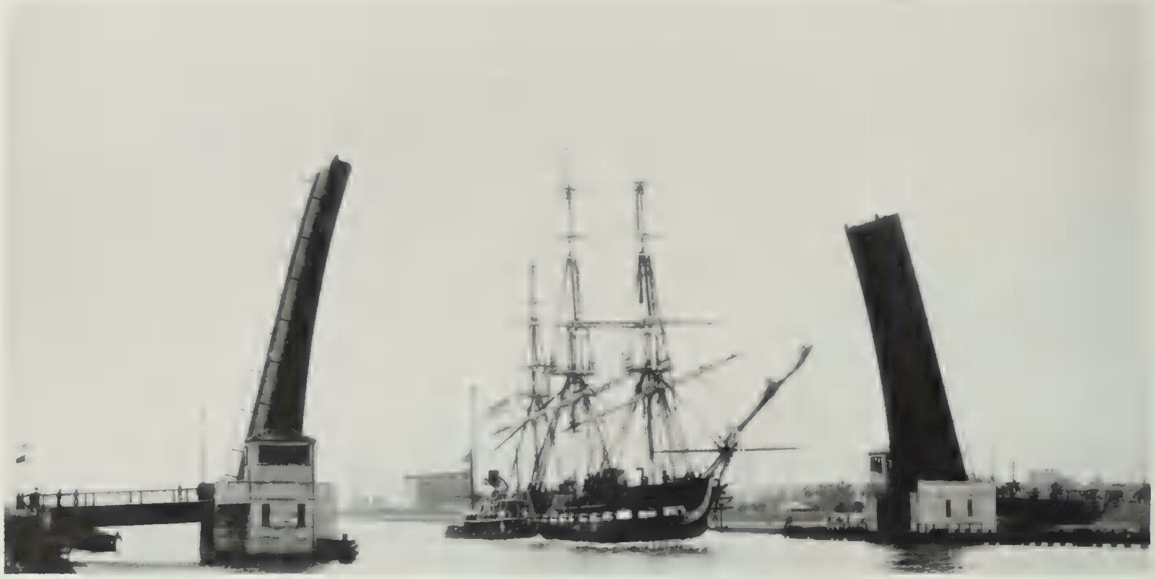


Figure 105. THE U. S. "CONSTITUTION" PASSING THROUGH A SCHERZER BASCULE BRIDGE, PORT ARTHUR, TEXAS

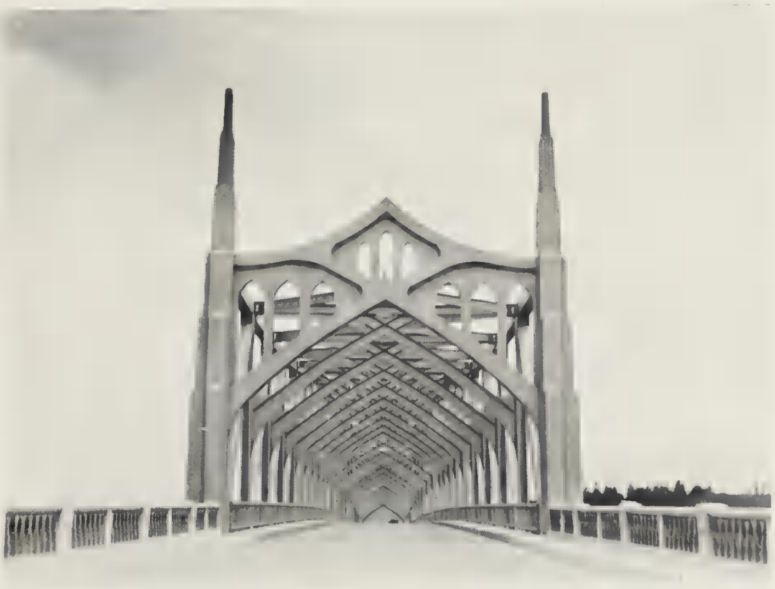


Figure 106. PORTAL VIEW, BRIDGE OVER COOS BAY,
OREGON COSTAL HIGHWAY

APPENDIX, A—CONTRACTORS

Principal Contracting Firms Responsible for the Construction of Bridges Included in Text

ALBANY, NEW YORK, HUDSON RIVER BRIDGE
- Booth and Flinn, General Contractors
- McClintic-Marshall Corporation, Subcontractors for Superstructure

BAYONNE, NEW JERSEY, BRIDGE OVER THE KILL VAN KULL
- H. P. Converse, Main bridge abutments
- P. T. Cox Contracting Company, Bayonne approach piers
- Arthur McMullen Company, Port Richmond approach piers
- American Bridge Company, Superstructure

BEAR MOUNTAIN, NEW YORK, BRIDGE OVER THE HUDSON RIVER
- The Terry & Tench Co., General
- The McClintic-Marshall Corporation, Structural Steel

BUFFALO, NEW YORK, THE PEACE BRIDGE
- J. P. & R. B. Porter, Ottawa, Substructure
- Bethlehem Steel Company, Superstructure

CALIFORNIA STATE HIGHWAY DEPARTMENT
- Bixby Creek Bridge, The Ward Engineering Company, San Francisco
- Klamath River Bridge, F. Rolandi
- Sacramento River Bridge, Consolidated Steel Corporation, Superstructure

CANON CITY, COLORADO, BRIDGE OVER THE ROYAL GORGE
- The Midland Bridge Company

CAPE COD, MASSACHUSETTS, BRIDGES OVER THE CAPE COD CANAL
- P. J. Carlin Construction Company, New York, Substructure for two highway bridges
- C. W. Blakeslee & Sons and Blakeslee-Rollins Corporation, Boston, Substructure for railroad bridge
- American Bridge Company, Superstructures of highway bridges
- The Phoenix Bridge Company, Superstructure of Railroad Bridge

CARQUINEZ STRAITS, CALIFORNIA, HIGHWAY TOLL BRIDGE
- Missouri Valley Bridge & Iron Company, Leavenworth, Kansas, Substructure
- U. S. Steel Products Company, Superstructure

CASTELMORON, FRANCE, HIGHWAY BRIDGE OVER RIVER LOT
- Christian and Nielson

CATSKILL, NEW YORK, THE RIP VAN WINKLE BRIDGE OVER THE HUDSON
- Frederick Snare Corporation, New York, General Contractors

CINCINNATI, OHIO, CHESAPEAKE & OHIO RY. BRIDGE OVER THE OHIO RIVER
- United Gas Improvement Company, Substructure
- American Bridge Company, Superstructure

CLEVELAND, OHIO, LORAIN-CARNEGIE BRIDGE OVER THE CUYAHOGA RIVER VALLEY
- The Lowensohn Construction Company, Cleveland, All piers except river piers, decking, paving, etc.
- The Walsh Construction Company, Davenport, Iowa, for two river piers
- The Mt. Vernon Bridge Company, Mt. Vernon, Ohio, Steel superstructure

CLEVELAND, OHIO, LORAIN ROAD VIADUCT OVER ROCKY RIVER
- The Lowensohn Construction Company, Cleveland, General contractors
- The Fort Pitt Bridge Company, Pittsburgh, Subcontractors for steel superstructure

CLEVELAND, OHIO, HILLIARD ROAD BRIDGE OVER ROCKY RIVER VALLEY
- The Walsh Construction Company, Davenport, Iowa

- COLUMBIA, PENNSYLVANIA, BRIDGE OVER THE SUSQUEHANNA RIVER
  - The Wiley-Maxon Construction Company, Dayton, Ohio
- CROWN POINT, NEW YORK, BRIDGE OVER LAKE CHAMPLAIN
  - Merritt, Chapman & Scott Corporation, Substructure
  - American Bridge Company, Superstructure
- DETROIT, MICHIGAN, AMBASSADOR BRIDGE OVER THE DETROIT RIVER
  - The McClintic Marshall Corporation, General Contractors
  - The Foundation Company, Subcontractors for main piers
- FLORIANAPOLIS, BRAZIL, SUSPENSION BRIDGE
  - Byington and Sundstrom, General Contractors, São Paula, Brazil
  - The American Bridge Company, Subcontractors for superstructure
  - The American Steel & Wire Company, Wire rope
- GRAND CANYON, ARIZONA, KAIBAB TRAIL BRIDGE
  - The Kansas City Structural Steel Co.
- GRAND ISLAND, NEW YORK, NIAGARA RIVER BRIDGES
  - Booth & Flinn, Pittsburgh, Substructures
  - Jones & Laughlin Steel Corporation and Fort Pitt Bridge Works for the steel superstructure of the south bridge, and the Taylor-Fichter Steel Construction Company for superstructure of the north bridge
- HARRISBURG, PENNSYLVANIA, MARKET STREET BRIDGE OVER THE SUSQUEHANNA RIVER
  - James McGraw Company, Philadelphia
- HARRISBURG, PENNSYLVANIA, SOLDIERS & SAILORS MEMORIAL BRIDGE
  - James McGraw Company, Philadelphia
- LONDON, NEW THAMES RIVER BRIDGE AT LAMBETH
  - Dorman, Long & Co., London and Middlesbrough, England
- LONGVIEW, WASHINGTON, HIGHWAY TOLL BRIDGE OVER THE COLUMBIA RIVER
  - The Bethlehem Steel Company, Superstructure
- LOUISVILLE, KENTUCKY, THE MUNICIPAL BRIDGE
  - The Vang Construction Company, Pittsburgh, Substructure main bridge
  - The American Bridge Company, Pittsburgh, Superstructure main bridge
  - The Henry Bickel Company, Approaches
- MAYSVILLE, KENTUCKY, HIGHWAY BRIDGE OVER THE OHIO RIVER
  - The Dravo Construction Company, Substructure
  - The John A. Roebling Sons Company, Cables
- MINNEAPOLIS, MINNESOTA, FORD BRIDGE OVER THE MISSISSIPPI RIVER
  - J. O. Heyworth, Chicago
- MINNEAPOLIS, MINNESOTA, FORT SNELLING-MENDOTA BRIDGE OVER THE MISSISSIPPI RIVER
  - The Koss Construction Company, Des Moines, Iowa
- MONTREAL, CANADA, HARBOR BRIDGE OVER THE ST. LAWRENCE RIVER
  - Dominion Bridge Company, Superstructure
- MORGAN CITY, LOUISIANA, ATCHAFALAYA BRIDGE
  - The Foundation Company, New York, Substructure
  - The Mt. Vernon Bridge Company, Mt. Vernon, Ohio, Superstructure
- NEWCASTLE, ENGLAND, THE NEW TYNE BRIDGE
  - Dorman, Long & Company, Ltd., London and Middlesbrough
- NEW ORLEANS, LOUISIANA, THE HUEY P. LONG BRIDGE OVER THE MISSISSIPPI RIVER
  - Siems-Helmers, Inc., Main substructures
  - McDonald Engineering Company, Approach substructures
  - American Bridge Company, Main bridge superstructure
  - McClintic Marshall Corporation, Approach superstructure

- NEWPORT NEWS, VIRGINIA, BRIDGE OVER JAMES RIVER
  - The Turner Construction Company, General contractors
  - The Raymond Concrete Pile Company, Subcontractors for piling
  - Sanford & Brooks, Baltimore, Subcontractors for piers
  - Virginia Bridge and Iron Works, Roanoke, Subcontractors for steel
- NEW JERSEY, PULASKI HIGHWAY BRIDGE OVER THE PASSAIC RIVER
  - The McClintic Marshall Corporation, Superstructure
- NEW YORK CITY, THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER
  - Silas B. Mason, Arthur McMullen, Cornell Contracting Company and Wm. P. McGarry Company for substructures and approaches
  - The John A. Roebling Sons Company, Cables
  - The McClintic-Marshall Corporation, Steel superstructure
- NEW YORK CITY, RECONSTRUCTION OF THE AQUEDUCT BRIDGE
  - P. T. Cox Contracting Company, General contractors
  - The McClintic-Marshall Corporation, Superstructure
- NEW YORK CITY, THE TRIBOROUGH BRIDGE
  - Taylor-Fichter Steel Construction Company, Superstructures
  - Corbetta Contracting Company, Manhattan approach
  - Tully & Di Napoli, Paving
  - Albert A. Volk Co., Paving
  - Poirier & McLane Corporation, Structural concrete
  - P. T. Cox Contracting Company, Structural concrete
- NEW YORK CITY, THE HENDRIK HUDSON BRIDGE
  - Thos. Crimmins Contracting Co., Substructure
  - American Bridge Co., Superstructure
- OHIO STATE HIGHWAY BRIDGES
  - BRECKSVILLE BRIDGE—The Highway Construction Co., Cleveland
  - BROOK PARK VIADUCT—The Highway Construction Co., Cleveland
  - PORT CLINTON BRIDGE—A. Bentley & Sons, Toledo, Substructure
    - R. C. Mahon, Superstructure
- OREGON STATE HIGHWAY BRIDGES
  - YAQUINA BAY—Gilpin Contracting Company, Portland and General Construction Company, Seattle
  - ALSEA BAY—Lindstrom & Feigenson, Parker & Banfield, T. H. Banfield
  - SUISLAW—Mercer Fraser Company, Eureka, California
  - UMPQUA RIVER—Teufel & Carlson, Seattle
  - COOS BAY—Northwest Roads Company, Portland; Virginia Bridge & Iron Co., Roanoke
  - ROGUE RIVER BRIDGE—Mercer Fraser Company, Eureka, California
- PADUCAH, KENTUCKY, HIGHWAY TOLL BRIDGE OVER THE OHIO RIVER
  - The Wisconsin Bridge Company
- PHILADELPHIA, PENNSYLVANIA, CAMDEN BRIDGE OVER THE DELAWARE RIVER
  - The Keystone Construction Company, Anchorages
  - The Holbrook, Cabot & Rollins Corporation, Piers
  - The Bethlehem Steel Corporation, Towers
  - The Keystone Construction Company, Cables
  - The American Bridge Company, Trusses
- PHILADELPHIA, PENNSYLVANIA, TACONY-PALMYRA BRIDGE OVER THE DELAWARE RIVER
  - The American Bridge Company, Superstructure

PITTSBURGH, PENNSYLVANIA, RECENT BRIDGES
  FORTIETH STREET BRIDGE OVER THE ALLEGHENY RIVER
    H. P. Converse Company, Boston, Substructure
    McClintic-Marshall Company, Superstructure
  SIXTH, SEVENTH AND NINTH STREET BRIDGES OVER THE ALLEGHENY RIVER
    The American Bridge Company, Superstructures
    The Foundation Company, Substructures
  WEST END-NORTH SIDE BRIDGE OVER THE OHIO RIVER
    American Bridge Company, Superstructure
    The Foundation Company, Substructure
  McKEES ROCKS BRIDGE OVER THE OHIO RIVER
    Fort Pitt Bridge Company, Superstructure
    Dravo Construction Company, Substructure
  GEORGE WASHINGTON BRIDGE
    The Booth & Flinn Company

PLOUGASTEL, FRANCE, BRIDGE OVER THE ELORN RIVER
  Limousin et Cie, Paris

POINT PLEASANT, WEST VIRGINIA, BRIDGE OVER THE OHIO RIVER
  General Contracting Company, Pittsburgh, General contractors
  American Bridge Company, Pittsburgh, Superstructure

POUGHKEEPSIE, NEW YORK, THE MID-HUDSON BRIDGE
  Blakeslee-Rollins Corporation, Substructure
  The American Bridge Company, Superstructure

PROVIDENCE, RHODE ISLAND, WASHINGTON STREET BRIDGE
  Merritt, Chapman & Scott Corporation

QUEBEC, BRIDGE AT ILE D'ORLEANS
  The Foundation Company of Canada, Substructure
  The Dominion Bridge Company, Superstructure

RHODE ISLAND, THE MT. HOPE BRIDGE
  Merritt, Chapman & Scott Corporation, Substructure
  The McClintic-Marshall Corporation, Superstructure
ROCHESTER, NEW YORK, THE VETERANS MEMORIAL BRIDGE OVER THE GENESEE RIVER
  Booth & Flinn, Pittsburgh, Pennsylvania
ROGUE RIVER BRIDGE, OREGON
  Mercer-Fraser Company, Eureka, California
ST. PAUL, MINNESOTA, ROBERT STREET BRIDGE
  Feagles Construction Co.
SAN FRANCISCO, CALIFORNIA, THE SAN FRANCISCO-OAKLAND BAY BRIDGE
  Healy-Tibbetts Construction Company, San Francisco anchorage
  Clinton Construction Co., Yerba Buena anchorage
  The Columbia Steel Company, all steel superstructures
  The Transbay Construction Company, West Channel piers
  Bridge Builders, Inc., East Channel piers
SAN FRANCISCO, CALIFORNIA, THE GOLDEN GATE BRIDGE
  The Pacific Bridge Company, Main piers
  The John A. Roebling Son's Company, Cables
  Barrett & Hilp, San Francisco, Anchorages
  The McClintic-Marshall Corporation, Superstructure—main span
  Bridge Builders, Inc., and Eaton & Smith, Approach spans

SEATTLE, WASHINGTON, LAKE UNION BRIDGE
  The Pacific Bridge Company, Portland, Oregon, Substructures
  D. Nydren, Seattle, Approaches
  United States Steel Products Company, Seattle, Superstructure
SOUTH AFRICA, BIRCHENOUGH BRIDGE OVER THE SADI RIVER
  Dorman, Long & Company, Ltd. London and Middlesbrough
STATEN ISLAND, NEW YORK, THE GOETHALS BRIDGE
AND THE OUTERBRIDGE OVER THE ARTHUR KILL
  GOETHALS BRIDGE—Bethlehem Steel Company, Superstructure
    Frederick Snare Corp. and Triest Contracting Company, Substructure
  OUTERBRIDGE—McClintic Marshall Corporation, Superstructure
    Cornell Contracting Company, Substructure
STOCKHOLM, SWEDEN, TRANBERG SOUND BRIDGE
  Verlag von Wilhelm Ernst & Sohn, Berlin
SUISUN BAY, CALIFORNIA, SOUTHERN PACIFIC RAILWAY BRIDGE
  Siems-Helmers, Inc., St. Paul, Minnesota, Substructure
  Columbia Steel Company, San Francisco, Superstructure
SYDNEY, NEW SOUTH WALES, BRIDGE OVER SYDNEY HARBOR
  Dorman, Long, Ltd., London & Middlesbrough
SYRACUSE, NEW YORK, GRADE CROSSING ELIMINATION
  The Walsh Construction Co., General Contractors
  The American Bridge Co., Superstructures
TOLEDO, OHIO, HIGHWAY SUSPENSION BRIDGE ACROSS THE MAUMEE RIVER
  H. P. Converse & Holmes Construction Co., Substructure
  McClintic-Marshall Corporation, Superstructure
VANCOUVER, CANADA, BURRARD STREET BRIDGE
  Hodgson, King & Marble and Dawson Wade & Co., Ltd., Substructure
  Dominion Bridge Company, Ltd. and Western Bridge Company, Ltd., Superstructure
VICKSBURG, MISSISSIPPI, A PRIVATELY OWNED TOLL BRIDGE OVER THE MISSISSIPPI
  United Gas Improvement Contracting Company, Substructure
  The American Bridge Company, Superstructure for river spans
VINCENNES, INDIANA, MEMORIAL BRIDGE
  Ferguson Construction Company, Roelsford, Illinois
WALDO-HANCOCK BRIDGE, MAINE
  Merritt, Chapman & Scott, Substructure
  American Bridge Company, Superstructure
WASHINGTON, D. C., ARLINGTON MEMORIAL BRIDGE
  H. P. Converse Company, Substructure
  Hunkin-Conkey Construction Co., Cleveland, Concrete superstructure
  The Phoenix Bridge Company, Steel draw span
WASHINGTON, D. C., CALVERT STREET BRIDGE
  The John W. Cowper Company, Buffalo, New York
WESTCHESTER COUNTY, NEW YORK
  Croton Lake Bridge, Mt. Vernon Bridge Company, Superstructure

APPENDIX B—BIBLIOGRAPHY

Selected Index to Descriptions in Technical Journals or Bridges Included in Text

ALBANY, NEW YORK, BRIDGE OVER THE HUDSON RIVER
Civil Engineering, May, 1933
BAYONNE, NEW JERSEY, BRIDGE OVER THE KILL VAN KULL
Described in Brochure published by American Bridge Company
BEAR MOUNTAIN, NEW YORK, BRIDGE OVER THE HUDSON RIVER
Engineering News-Record, October 23, 1924
BUFFALO, NEW YORK, THE PEACE BRIDGE
Engineering News-Record, April 21, 1927 (Substructure only), May 10, 1927 (Superstructure)
CALIFORNIA STATE HIGHWAY DEPARTMENT, BIXBY CREEK BRIDGE
Engineering News-Record, Vol. 110 (1933) Page 467
CANON CITY, COLORADO, BRIDGE OVER THE ROYAL GORGE
Engineering News-Record, Vol. 104 (1930), Page 922
CAPE COD, MASSACHUSETTS, BRIDGES OVER THE CAPE COD CANAL
A good detailed description of these bridges is given in *Engineering News-Record* for January 25, 1934
CARQUINEZ STRAITS, CALIFORNIA, HIGHWAY BRIDGE
Engineering News-Record, May 12, 1927
CASTELMORON, FRANCE, HIGHWAY BRIDGE OVER THE RIVER LOT
Engineering News-Record, April 25, 1935
CATSKILL, NEW YORK, THE RIP VAN WINKLE BRIDGE OVER THE HUDSON RIVER
Engineering News-Record, November 7, 1935
CINCINNATI, OHIO, RAILROAD BRIDGE OVER THE OHIO RIVER
Trans. American Society of Civil Engineers, Vol. 99 (1934)
CLEVELAND, OHIO, LORAIN-CARNEGIE BRIDGE OVER CUYAHOGA RIVER VALLEY
Civil Engineering, November, 1932
CLEVELAND, OHIO, HILLIARD ROAD BRIDGE
Engineering News-Record, November 25, 1926
CLEVELAND, OHIO, LORAIN ROAD VIADUCT OVER ROCKY RIVER
Engineering News-Record, July 9, 1936
COLOGNE, GERMANY, THE COLOGNE MÜLHEIM BRIDGE
Karl Möhringer, *The Bridges of the Rhine*. Joh. Möhringer, Baden, 1931
COLUMBIA, PENNSYLVANIA, SUSQUEHANNA RIVER BRIDGE
Engineering News-Record, Vol. 103 (1929), Page 509
CROWN POINT, NEW YORK, BRIDGE OVER LAKE CHAMPLAIN
Described in *Trans. American Soc. of Civil Engineers*, Volume 98 (1933)
DENMARK, BRIDGE OVER THE LITTLE BELT
Civil Engineering, July, 1933
DETROIT, MICHIGAN, AMBASSADOR BRIDGE OVER THE DETROIT RIVER
A complete description of this bridge is given in a book published by the General Contractors
FORIANAPOLIS, BRAZIL, SUSPENSION BRIDGE
Described in *Trans. Amer. Soc. of Civil Engineers*, Volume 92
GRAND CANYON, ARIZONA, KAIBAB TRAIL BRIDGE
Engineering News-Record, June 5, 1930
GRAND CANYON, ARIZONA, ARCH BRIDGE OVER COLORADO RIVER
Ibid, Vol. 100

BIBLIOGRAPHY, Continued

GRAND-MERE, QUEBEC, SUSPENSION BRIDGE
Engineering News-Record, December 19, 1929

HARRISBURG, PENNSYLVANIA, MARKET STREET BRIDGE OVER THE SUSQUEHANNA RIVER
Engineering News-Record, June 21, 1928

HARRISBURG, PENNSYLVANIA, SOLDIERS AND SAILORS MEMORIAL BRIDGE
Engineering News-Record, September 4, 1930

KOBLENZ, GERMANY, THE ADOLPH HITLER BRIDGE OVER THE MOSELLE RIVER
Zeitschrift des Vereines Deutscher Ingenieure, June 16, 1934.

LA ROCHE GUYON, FRANCE, CONCRETE BRIDGE OVER SEINE
Le Genie Civil, February 9, 1935

LONDON, NEW THAMES RIVER BRIDGE AT LAMBETH
Engineering News-Record, March 31, 1932

LONGVIEW, WASHINGTON, HIGHWAY BRIDGE OVER THE COLUMBIA RIVER
Engineering News-Record, Vol. 104

LOUISVILLE, KENTUCKY, THE MUNICIPAL BRIDGE
A complete description of the project is contained in the Engineer's final report, published in book form

MAYSVILLE, KENTUCKY, HIGHWAY BRIDGE OVER THE OHIO RIVER
Engineering News-Record, November 25, 1932

MINNEAPOLIS, MINNESOTA, FORD BRIDGE OVER THE MISSISSIPPI RIVER
Engineering News-Record, November 10, 1927

MONTREAL, CANADA, BRIDGE OVER THE ST. LAWRENCE RIVER
Canadian Engineer, November 2, 1926 and Brochure published by the Dominion Bridge Co.

MORGAN CITY, LOUISIANA, ATCHAFALAYA BRIDGE
Described in *Engineering News-Record*, December 28, 1933

NEWCASTLE, ENGLAND, THE NEW TYNE BRIDGE
Described in Brochure published by the contractors

NEW JERSEY, PULASKI HIGHWAY BRIDGE OVER THE PASSAIC RIVER
Described in *Trans. of Amer. Soc. of Civil Engineers*
Volume 100 and *Civil Engineering*, March 1933

NEW ORLEANS, LOUISIANA, THE HUEY P. LONG BRIDGE OVER THE MISSISSIPPI RIVER
Engineering News-Record, May 10, 1934
Civil Engineering, December, 1935

NEWPORT NEWS, VIRGINIA, BRIDGE OVER THE JAMES RIVER
Trans. Amer. Soc. of Civil Engineers, 1931

NEW YORK CITY, THE GEORGE WASHINGTON BRIDGE OVER THE HUDSON RIVER
Completely described in Volume 97, *Trans. Amer. Soc. of Civil Engineers*, 1933

NEW YORK CITY, RECONSTRUCTION OF THE AQUEDUCT BRIDGE
American Architect, January 5, 1929 and April 5, 1929
Engineering News-Record, December 1, 1927

NEW YORK CITY, THE TRIBOROUGH BRIDGE
Engineering News-Record, Volume 102, Page 411
Civil Engineering, August, 1936

NEW YORK CITY, HENDRIK HUDSON BRIDGE
Engineering News-Record, August 13, 1936
Construction Methods for December, 1936

BIBLIOGRAPHY, Continued

OHIO STATE HIGHWAY BRIDGES

Brookpark Viaduct, *Engineering News-Record,* October 11, 1934
Port Clinton Bridge, described in *Engineering News-Record,* March 29, 1934

OREGON, STATE HIGHWAY BRIDGES

Yaquina Bay
Alsea Bay
Suislaw *Civil Engineering,* October, 1936
Umpqua River
Coos Bay
Rogue River Bridge, complete description in *Engineering News-Record,* November 26, 1931

PADUCAH, KENTUCKY, HIGHWAY BRIDGE OVER THE OHIO RIVER

Engineering News-Record, Vol. 102

PHILADELPHIA, PENNSYLVANIA, CAMDEN BRIDGE OVER THE DELAWARE RIVER

Described in brochure by Chas. Carswell, Enterprise Publishing Co., Philadelphia

PHILADELPHIA, PENNSYLVANIA, TACONY-PALMYRA BRIDGE OVER THE DELAWARE RIVER

Engineering News-Record, August 22, 1929

PITTSBURGH, PENNSYLVANIA, RECENT BRIDGES

Thirty-First Street bridge over the Allegheny River
Engineering News-Record, Vol. 101, Page 669
Sixth, Seventh and Ninth Street bridges over the Allegheny River
Engineering News-Record, September 23, 1936
Washington Crossing Bridge, described in brochure published by Allegheny County
McKees Rocks, *Engineering News-Record,* April 23, 1931

PLOUGASTEL, FRANCE, BRIDGE OVER THE ELORN RIVER

Architectural Forum, October, 1931
Engineering News-Record, October 31, 1929

POINT PLEASANT, WEST VIRGINIA, BRIDGE OVER THE OHIO RIVER

Engineering News-Record, June 20, 1929

PROVIDENCE, RHODE ISLAND, WASHINGTON STREET BRIDGE

Engineering News-Record, September 25, 1930

POUGHKEEPSIE, NEW YORK, THE MID-HUDSON BRIDGE

Described in brochure published by The American Bridge Company, written by F. W. Skinner

QUEBEC, CANADA, BRIDGE AT ILE D'ORLEANS

Engineering News-Record, March 15, 1934

RHODE ISLAND, THE MT. HOPE BRIDGE

Engineering News-Record, April 12, 1928

ROCHESTER, NEW YORK, THE VETERANS MEMORIAL BRIDGE OVER THE GENESEE RIVER

Architecture, April, 1932

ROGUE RIVER, OREGON, STATE HIGHWAY BRIDGE

Engineering News-Record, Vol. 107

ST. JOSEPH, MISSOURI, BRIDGE OVER THE MISSOURI RIVER

Engineering News-Record, Vol. 102

ST. PAUL, MINNESOTA, ROBERT STREET BRIDGE

Described in *Engineering News-Record,* November 4, 1926

SAN FRANCISCO, CALIFORNIA, THE SAN FRANCISCO-OAKLAND BAY BRIDGE

Civil Engineering, April, 1934, December, 1934, February, 1935
Also Brochure published by The American Bridge Company

BIBLIOGRAPHY, Continued

SAN FRANCISCO, CALIFORNIA, THE GOLDEN GATE BRIDGE
Described in Brochure by E. Cromwell Mensch, San Francisco
And *American Architect*, February, 1931
SEATTLE, WASHINGTON, LAKE UNION BRIDGE
Civil Engineering, September, 1931
SOUTH AFRICA, BRIDGE OVER THE SADI RIVER
Engineering News-Record, June 7, 1934
SPAIN, BRIDGE OVER THE ELSA RIVER
Ibid. Vol. 114
STATEN ISLAND, NEW YORK, BRIDGES OVER THE ARTHUR KILL
Ibid. August 26, 1926 and November 10, 1927
STOCKHOLM, SWEDEN, TRANBERG SOUND BRIDGE
Ibid. June 7, 1934
SUISUN BAY, CALIFORNIA, SOUTHERN PACIFIC RAILWAY BRIDGE
Described in Vol. 99, Trans. Amer. Soc. of Civil Engineers
SYDNEY, NEW SOUTH WALES, BRIDGE OVER SYDNEY HARBOR
Described in Brochure published by the contractors
SYRACUSE, NEW YORK, GRADE CROSSING ELIMINATION
Engineering News-Record, December 24, 1936
TOLEDO, OHIO, BRIDGE OVER MAUMEE RIVER
Engineering News-Record, Vol. 103
VANCOUVER, BRITISH COLUMBIA, BURRARD STREET BRIDGE
Engineering News-Record, February 23, 1933
VICKSBURG, MISSISSIPPI, HIGHWAY BRIDGE OVER THE MISSISSIPPI RIVER
Engineering News-Record, Vol. 103
VINCENNES, INDIANA, GENERAL GEO. ROGERS CLARK MEMORIAL BRIDGE
Engineering News-Record, September 7, 1933
WALDO-HANCOCK BRIDGE, MAINE
Described in *Engineering News-Record*, March 17, 1932
WASHINGTON, D. C., ARLINGTON MEMORIAL BRIDGE
Described in *The Military Engineer*, March and April, 1928 and November and December, 1930
WASHINGTON, D. C., CALVERT STREET BRIDGE
Engineering News-Record, February 21, 1935
WESTCHESTER COUNTY, NEW YORK, BRIDGES
Architectural Forum for May, 1928

GEOGRAPHICAL INDEX

Page

- Arizona
  - Grand Canyon, Bridge over Colorado River . . . 27
  - Grand Canyon, Kaibab Trail Bridge . . . 27
- California
  - Bixby Creek Bridge . . . 5
  - Carquinez Straits Highway Bridge . . . 7
  - Douglas Memorial Bridge . . . 5
  - Miller, H. D. Memorial Bridge . . . 5
  - San Francisco, Golden Gate Bridge . . . 92
  - San Francisco, Oakland Bay Bridge . . . 84
  - Suisun Bay Bridge . . . 97
- Colorado
  - Canon City, Bridge over Royal Gorge . . . 7
- District of Columbia . . . 104
  - Washington, Arlington Bridge . . .
  - Calvert Street Bridge . . . 107
- Illinois . . . 27
  - Freeport, Small Bridge . . .
- Indiana . . . 103
  - Vincennes, Memorial Bridge . . .
- Kentucky . . . 35
  - Louisville, The Kentucky and Indiana Terminal Ry. Bridge . . .
  - Louisville, The Municipal Bridge . . . 34
  - Maysville, Bridge over the Ohio River . . . 37
  - Paducah, Bridge over the Ohio River . . . 60
- Louisiana
  - Morgan City, Bridge over the Atchafalaya River . . . 38
  - New Orleans, Bridge over the Mississippi River . . . 40
- Maine
  - Waldo-Hancock Bridge . . . 103
  - Bucksport, See Waldo-Hancock Bridge . . . 103
- Massachusetts
  - Bourne, See Cape Cod Canal . . . 9
  - Cape Cod Canal, Highway Bridge at Bourne . . . 9
  - Railroad Lift Bridge . . . 9
- Michigan
  - Detroit, Ambassador Bridge over Detroit River . . . 20
- Minnesota
  - Fort Snelling-Mendota Bridge . . . 37
  - Minneapolis, The Ford Bridge . . . 37
  - St. Paul, The Robert Street Bridge . . . 83
- Mississippi
  - Vicksburg, Bridge over the Mississippi River . . . 102

GEOGRAPHICAL INDEX, Continued

Missouri Page
  St. Joseph, Bridge over the Missouri River 83
New Jersey
  Kill van Kull Bridge at Bayonne 1
  Pulaski Highway Bridge 44
New York
  Albany, over the Hudson 1
  Bear Mountain over Hudson 4
  Buffalo, The Peace Bridge over the Niagara River 4
  Catskill, Rip Van Winkle Bridge over Hudson 8
  Crown Point, Bridge over Lake Champlain 19
  Grand Island, Bridge over Niagara River 28
  New York City, The George Washington Bridge 44
    "High Bridge" reconstruction 52
    The Tri-borough Bridge 53
  Poughkeepsie, Mid-Hudson Bridge 75
  Rochester, Veterans Memorial Bridge 78
  Staten Island, The Goethals Bridge 96
    The Outerbridge 96
  Westchester County, Croton Lake Bridge 107
  Hendrik Hudson Bridge 43
Ohio
  Cincinnati, Chesapeake & Ohio Railroad Bridge 10
  Cleveland, Brookpark Road Viaduct 56
    Hilliard Road Bridge over Rocky River 11
    Lorain-Carnegie Viaduct 11
    Lorain Road Viaduct 16
  Port Clinton, Draw Bridge 56
  Toledo, Suspension Bridge over the Maumee River 102
Oregon
  Rogue River Bridge 82
  State Highway Bridges on Coast Highway 56
Pennsylvania
  Columbia, Bridge over the Susquehanna 19
  Harrisburg, Market Street Bridge over the Susquehanna 30
    Soldiers and Sailors Memorial Bridge 30
  Philadelphia, Pennsylvania Railroad Bridge 64
    The Philadelphia-Camden Bridge 60
    Tacony-Palmyra Bridge over the Delaware 60
  Pittsburgh, Fortieth Street Bridge 66
    George Westinghouse Bridge 71
    McKee's Rocks Bridge 68
    Point Bridge 66
    Sixteenth Street Bridge 68
    Sixth Street Bridge 68

GEOGRAPHICAL INDEX, Continued

Page

Thirty-first Street Bridge 66
West End-North Side Bridge 67
Rhode Island
Mt. Hope Bridge 76
Providence, Washington Street Bridge 76
New York
Syracuse, Grade Crossing Elimination 101
Virginia
James River Bridge 42
Washington
Longview, Bridge over the Columbia River 34
Seattle, Lake Union Bridge 96
West Virginia
Point Pleasant Bridge 73
Australia
Sydney, The Harbor Bridge 99
Belgium
Eyne, Memorial Bridge 23
Brazil
Florianapolis Bridge 26
British Columbia, Vancouver, Burrard Street Bridge 102
Canada
Quebec, Ille d'Orleans Bridge 76
Montreal, The Harbor Bridge 38
Denmark
Bridge over the Little Belt 23
England
London, Lambeth Bridge 33
Newcastle, Tyne Bridge 40
France
Paris, Pont de la Tournelle 60
Ploughgastel, Elorn River Bridge 72
Germany
Cologne, The Muelheim Bridge 16
South Africa
Bridge over Sadi River 96
Spain
Bridge over Elsa River 96
Sweden
Stockholm, Tranberg Sound Bridge 97

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